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Annual Dinner of the Institute of Marine Engineers

THE fifty-first annual dinner of the Institute of Marine Engineers was held on Friday, March 12th, at Grosvenor House, Park Lane, London, W.1, and was attended by over 1000 members and their guests, who were received by the President, Sir Gilmour Jenkins. After the loyal toasts were honoured, His Excellency M. D. W. Stikker, the Netherlands Ambassador, proposed the toast of "The Royal and Merchant Navies of the British Commonwealth," and said that he was descended from a family of shipbuilders, shipowners and navigators, one of whom had sailed up the Thames to Chatham on a well-known occasion. Turning to the present and the immediate past, he commented upon the common struggle and efforts of the two countries and upon the influence of the sea, and then went on to recall that the Navy was a safeguard to freedom and dignity. The coming into being and the growth of the Commonwealth could be attributed, he felt, to the Royal and Merchant Navies which carried culture and civilisation to distant lands. In his reply Admiral F. T. Mason, the Engineer-in-Chief of the Fleet, recalled a recent visit to Holland where he had been impressed by the reconstruction of the war-damaged shipyards and the rapid construction of ships. He continued by briefly reviewing the beginnings of the Royal Navy and then touched upon some of the development work which was being carried out in the Navy's frigates. "The Institute of Marine Engineers" was proposed by the Right Honourable A. T. Lennox-Boyd, M.P., who recounted some naval reminiscences and praised the work of engineers in many fields. The president, Sir Gilmour Jenkins, in his reply, mentioned the record increase in membership, particularly student membership, during 1953, and announced that the building scheme was going forward and that additional funds were required to finance the project.

Experiences with British Railways Standard Locomotives

ON Wednesday last, Mr. E. S. Cox, the Executive Officer (Design), British Transport Commission, presented a paper, "Experiences with British Railways Standard Locomotives," to the Institution of Locomotive Engineers. In introducing the paper, the author pointed out that eleven of the twelve proposed standard types of steam locomotives were now in service. It was not possible within a single paper to survey every aspect of experience with the engines, and Mr. Cox therefore decided to concentrate principally on two types. The first part of his paper dealt with performance and efficiency in operation, and the second part gave an account of the more outstanding teething troubles experienced with the locomotives and the ways in which they were overcome. In dealing with the mechanical performance of the locomotives, Mr. Cox said that while in general things went according to the designer's intentions, there were some troubles, most of which had been overcome. Some surprises were experienced where details which were adopted with trepidation did not eventually give any trouble, whilst others, thought from past experience to be reliable, gave trouble. In his conclusion to the paper, Mr. Cox said that we were undoubtedly entering upon the last phase of steam traction in this country and its disadvantages had been sufficiently publicised, although while it lasted the steam locomotive had certain good factors which should not be ignored. Steam locomotives could be overloaded to stalling point without injuring themselves; defects were easy to diagnose and seldom expensive to rectify; first costs were cheap, and as this was a coal-bearing country the steam locomotive was nearly as cheap in fuel costs for many duties as its much more efficient and higher priced rivals.

National Factory Equipment Exhibition

THE second National Factory Equipment Exhibition will be opened at the Royal Horticultural Society's Hall, Westminster, S.W.1, by Lord Rochdale, on Monday next, March 22nd. At this exhibition, which will remain open until Friday, March 26th, about 130 firms will display a comprehensive range of equipment and products of particular interest to the administrative and executive side of industry. During the exhibition a series of conferences will be held under the auspices of the British Productivity Council and the Institute of Works Managers. The British Productivity Council conferences will be held on Tuesday, March 23rd and Thursday, March 25th. On the first day four papers will be read and discussed: "Fundamentals of Economic Production," by Mr. C. R. Wynne-Roberts; "Machine Utilisation," by Mr. John Loxham; "The Approach to Productivity," by Mr. J. Marsh, and "Fuel Conservation," by Mr. W. L. Boon. On the Thursday two sessions will be held, one dealing with "Work Study," introduced by Mr. A. J. Speakman, and one on "Productivity—Some Practical Suggestions," introduced by Mr. Bertram White. The London branch of the Institute of Works Managers has organised discussions on "Management and Productivity" for Wednesday, March 24th. One discussion, under the chairmanship of Mr. T. L. Nuttall, will consider how productivity can be increased in this country; the other, under the chairmanship of Mr. John Ayres, will consider the effect of labour relations on productivity.

Researches for Fuel Conservation

ON Monday last, March 15th, an interesting talk entitled "Some Engines which Save Fuel," was given by Sir Harold Roxbee Cox at the Old Centralians' luncheon. Sir Harold said that a considerable volume of research work, aimed at the conservation of fuel supplies, was in progress. He did not think that atomic energy would be able to make a significant contribution to the nation's power requirements for some time, and its economic aspects had still to be determined; moreover, the ultimate pattern of fuel requirements was not yet clear. Other researches, therefore, had still to be carried on, aimed either at utilising new fuels, such as wind power, or at increasing the efficiency with which common fuels were consumed. Sir Harold then briefly outlined various possible applications of gas turbines in this field of research, such as the use of open or closed cycle gas turbines burning pulverised coal, which, he thought, showed promise of ultimately giving a thermal efficiency of about 45 per cent. Peat-burning gas turbines had also been developed, Sir Harold continued, and an improved press had been developed for using the Madruck peat-drying process. Transport of peat was a problem, and one possible solution was to utilise gas turbines which could be moved across the peat bog as consumption proceeded. Another interesting application of the gas turbine which Sir Harold mentioned during his talk was that of burning natural gas, including the weak mixture containing about 0·5 per cent of methane, which was exhausted from many colliery upshafts. A dual-fuel gas turbine would shortly be operated, he said, which would preheat and burn this weak mixture, and would ultimately use as an alternative fuel colliery "fines," which would otherwise be wasted.

Shipping and Invisible Exports

THE inquiry by the General Council of British Shipping into the contribution made by the shipping services of the United Kingdom towards the balance of trade for 1952 has been completed and the Council has sent its first report to the Minister of Transport. As a result of the inquiry it has been established that a net sum of £221 million in foreign exchange was earned by ships either owned in the United Kingdom or operated by shipowners in the country, which compares with the sum of £60 million earned in 1947, the year when the last similar inquiry was undertaken. The earnings given, it is stated, are in no way related to the net profits of the United Kingdom shipping companies since expenses incurred in this country are not included in the calculations concerned with earnings and disbursements of foreign currency. British shipping is engaged in three main trades, namely, imports into this country, exports from this country and cross trades such as those between one commonwealth or foreign country and another. Foreign exchange earnings are stated to represent the freights on exports and cross voyages less the disbursements incurred abroad, including the expenses of United Kingdom ships bringing imports to this country. Thus the amount of the earnings of foreign exchange as given is a strictly net figure. The freights on imports carried in British ships are not included in contributions of shipping to invisible exports as revealed by the inquiry, although it is claimed that such services, which amounted to £218 million for 1952, by saving the expenditure of foreign exchange make an indirect contribution to the balance of payments.

Report on "Royal Scot" Derailment

ON August 8, 1953, the last seven coaches of the "Royal Scot" express train from Euston to Glasgow were derailed, near Abington Station, on the northward descent from the Beattock summit in the Scottish Region of British Railways. The Ministry of Transport has now issued the report of the inquiry into this derailment, which was conducted by Lieut.-Colonel G. R. S. Wilson. There were 312 passengers in the train, but fortunately there were no very serious injuries either to the passengers or train staff as a result of the derailment. The train was running at about 60 m.p.h., and the report says that "the afternoon had been unusually warm for the locality." There was little doubt from the outset of the investigation, the report continues, that the rails had not been expanding freely as their temperature rose, and that the resulting heavy compressive stress had been suddenly released to buckle the track as the leading coaches of the train passed over it. In some remarks about the derailment, Lieut.-Colonel Wilson says in his report that experience in the Scottish Region has shown that bull-head track adjacent to heavy and rigid flat-bottom track is particularly liable to distortion in hot weather if maintenance is not good. Rail creep, with its effect in destroying the regularity of the expansion gaps, has always presented a problem in track maintenance, especially on falling gradients and when there is heavy braking, and it contributed to this derailment. The need for creep to be adjusted in good time before the summer, Lieut.-Colonel Wilson adds, has been stressed, but there is no doubt that the operation is troublesome on flat-bottom track fastened with elastic spikes, as 144 spikes have to be drawn in each 60ft rail length and re-driven after the rails have been pulled back. While it is impossible to guarantee that there will be no compression at all in the rails on the hottest days, it can be kept within bounds, the report says, by timely attention to creep.

Recording Signals from Resistance Strain Gauges

By D. A. SENIOR, M.A., A.M.I.E.E.*

No. I—INTRODUCTION AND GALVANOMETER DESIGN

The low level of the output signal from resistance strain gauges has hitherto been overcome by means of electronic amplifiers with their added complication and cost. It is, however, possible to dispense with amplifiers by using sensitive galvanometers of suitable design. The galvanometer is coupled directly across a Wheatstone bridge of which the strain gauge forms one arm, and enables static and low frequency dynamic strains to be recorded provided that sufficient power can be dissipated in the strain gauge. Galvanometers of the moving coil type are discussed in this paper as it seems that these will prove to be the most suitable for the purpose. The optimum design is determined and the practical limits explored. The aim is to provide a record readable to ±2 per cent for static and ±5 to 6 per cent for dynamic strains over the maximum range of frequencies, full scale being the equivalent of a stress of 5 tons per square inch in steel. An experimental galvanometer is described which works with a strain gauge dissipating 4W and covers a frequency range from 0 to 65 c/s. Theory shows that certain improvements in galvanometer construction should enable this frequency range to be covered with much lower power dissipation, possibly as low as 0·5W.

THE wire resistance strain gauge and more recently the printed resistance strain gauge† provide a very valuable method of measuring strains in structures and thereby carrying out stress analysis. The gauges are cheap and, so long as reasonable care is taken, give reliable results over long periods of use. Their chief disadvantage is that the output signal is at a low level. A stress of 5 tons per square inch in steel for example gives rise to a strain of 1/2900. This causes a proportionate resistance change in the gauges commonly in use of about 1/1500. If the gauge forms one arm of a Wheatstone bridge with equal arms, this resistance change leads to a maximum output power from the bridge of $2\cdot8\times10^{-6}$W per watt dissipated as heat in the strain gauge. As the gauges are generally run at 0·05W to 0·1W it is clear that a sensitive measuring device must be used.

With static strains a microammeter or galvanometer may be connected directly across the bridge but in recording dynamic strains, electronic amplification is generally used and the inherent simplicity and cheapness of direct observation are lost.

It is, however, possible to increase the output signal by running the gauges at a much higher power dissipation than is commonly the practice.[1] Low frequency dynamic signals may then be recorded directly by means of suitably designed high sensitivity galvanometers. There are three existing types of galvanometer suitable for the purpose :—

(1) The D'Arsonval galvanometer in which a small coil and mirror are suspended on conducting tapes in a magnetic field, and rotated by the interaction of the field and the current flowing in the coil.

(2) The Einthoven galvanometer in which a single current carrying wire is mounted in a state of tension in a magnetic field and its deflection recorded.

(3) The Duddell galvanometer in which two wires are used. These are bridged at their centre by a small mirror so that the deflection of the wires imparts a rotation to the mirror.

In all three cases the record is made on moving photographic film or paper, with the D'Arsonval and Duddell galvanometers by the moving spot of light reflected from the mirror and with the Einthoven galvanometer by the magnified image of a portion of the wire itself.

The D'Arsonval and Einthoven[2] galvanometers have both been used successfully in recording dynamic strains. The Duddell, though theoretically as satisfactory as the other two involves practical difficulties and so far as is known has not been used for the purpose.

This paper is concerned with the factors influencing the design of the D'Arsonval galvanometer which seems the most suitable of the three, for it is compact, ideally suited to multi-channel use and extremely robust.

The Design Problem

It is required to record strains of the highest possible frequency. The fundamental parameters are the strain sensitivity required and the power dissipation of the strain gauge.

The strain sensitivity (i.e. the movement of the spot of light on the film for a given strain in the specimen to which the gauge is attached) depends upon the maximum strain to be recorded and the accuracy required of the record. A maximum strain of 1/2900, equivalent to a stress of 5 tons per square inch in steel, will be taken, for the method is not suitable for very low strains unless they are static. A full-scale deflection of 1·5cm with an optical lever of 28cm is taken, to give a record readable to ±1 per cent of the full-scale deflection.

A tolerance of ±5 per cent over the whole frequency range is accepted but this applies only to the frequencies where amplitude and phase distortion of the signal are worst. The shape of the amplitude/frequency response curve depends on the damping of the motion of the coil. If this is arranged to be 0·6 of critical, the amplitude is correct within 1 per cent up to 0·22 of the natural frequency of undamped mechanical oscillations of the coil on its suspension, within 2·5 per cent up to 0·32 of the natural frequency, and within 5 per cent up to 0·86 of the natural frequency. The phase lag, moreover, varies linearly with the frequency, within 5 per cent, up to 0·75 of the natural frequency. From a consideration of amplitude and phase distortion therefore, a damping factor of 0·6 is generally accepted as the best compromise.

The permissible strain gauge power dissipation is determined in practice by the failure of the matrix of the gauge to transmit the strain from the specimen to the wires of the gauge. Slip thus occurs when the self-heating of the gauge begins to cause softening of the matrix. It is more realistic to consider the power dissipated by the gauge since this determines the temperature, than the current which is also a function of the electrical resistance of the gauge. It has been found practicable to construct gauges of 200 ohms resistance which will dissipate powers of 4W under certain conditions.

In the analysis of the problem which follows, the natural frequency of the galvanometer, which determines the range of frequencies which can be recorded, is related to the parameters already mentioned and to those involved in the design of the galvanometer itself. Referring to Fig. 1, which shows a typical coil, wound on two ivory bobbins, these are :—

(1) The number of turns of wire in the coil N.

(2) The length L and breadth B of the winding.

(3) The inertia of the inactive parts of the moving system, i.e. that of the bobbins and mirror.

(4) The inertia of the active part of the moving system, i.e. that of the wire, and

(5) The strength of the magnetic field in which the coil is immersed, H.

It is convenient to express the performance of the galvanometer in terms of the parameters already mentioned and two further quantities which are derived from them :—

(1) The mismatch m, i.e. the ratio of the resistance of the strain gauge to that of the coil, and

(2) The torsional rigidity of the suspension K.

Analysis

The strain gauge is arranged to form one arm of a Wheatstone bridge. A source of direct current is applied to two opposite corners and the galvanometer is connected across the other two. Consider the case when all four arms of the bridge are initially equal. Then the out of balance current which flows through the galvanometer coil may be shown to be :—

$$I_G=\frac{V\delta(mR_G)}{4(m+1)mR_G^2} \quad . \quad . \quad . \quad . \quad (1)$$

practical amperes, where V is the applied d.c. potential in practical volts, R_G is the resistance of the galvanometer in practical ohms, m the mismatch so that mR_G is the resistance of one arm of the bridge and $\delta(mR_G)$ is the change in the resistance of the strain gauge due to the strain in the material to which the gauge is attached.

The power dissipated in the strain gauge is W practical watts, so

$$V=2(WmR_G)^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Let the gauge factor of the strain gauge be k and the strain ϵ. Then the proportionate change of resistance is $k\epsilon$, that is :—

$$\frac{\delta(mR_G)}{mR_G}=k\epsilon \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Eliminating V and $\delta(mR_G)$ between equations (1), (2) and (3),

$$I_G=\frac{k\epsilon(mW)^{\frac{1}{2}}}{2(m+1)R_G^{\frac{1}{2}}} \quad . \quad . \quad . \quad . \quad (4)$$

The deflection of the galvanometer coil is given by the equation :—

$$\theta=\frac{HNAI_G}{10K} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

radians, where H is the magnetic field strength in oersteds, N the number of turns of wire in the coil, A the area of cross section of the coil in square centimetres (equal to the product LB), and K the torsional rigidity of the suspension in dyne cm per radian.

Substituting for I_G from equation (4),

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† Developed by Saunders Roe, Ltd., and Technograph, Ltd. See *Aircraft Engineering*, Vol. 24, November, 1952, and *Instrument Practice*, Vol. 7, No. 10, August, 1953.

$$\frac{K(m+1)}{m^{\frac{1}{2}}}=\frac{HNAk\epsilon W^{\frac{1}{2}}}{20R_G^{\frac{1}{2}}\theta} \quad . \quad . \quad (6)$$

The electromagnetic damping is given by the expression :—

$\frac{H^2N^2A^2 10^{-9}}{(m+1)R_G}$ dyne cm per radian per second, while critical damping is given by the expression : $2(KJ)^{\frac{1}{2}}$, where J is the total inertia of the system in gm. cm^2.

Thus :—

$$\frac{H^2N^2A^2 10^{-9}}{(m+1)R_G}=2h(KJ)^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad (7)$$

where h is the degree of damping.

Hence :—

$$K^{\frac{1}{2}}(m+1)=\frac{H^2N^2A^2 10^{-9}}{2hR_GJ^{\frac{1}{2}}} \quad . \quad . \quad (8)$$

Eliminating K between equations (6) and (8),

$$m(m+1)^2=25.10^{-36}\cdot\frac{H^6N^6A^6\theta^2}{h^4R_G^3J^2k^2\epsilon^2W} \quad (9)$$

The required mismatch m is given by equation (9). The suspension rigidity is given by substitution of the value of m in equation (6) or equation (8).

The natural frequency f is then given by the equation :—

$$f=\frac{1}{2\pi}\left(\frac{K}{J}\right)^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad (10)$$

cycles per second. This determines the range of recording frequencies.

The maximum range is obtained when f itself is a maximum, so it is required to select H, N, A, R_G W, $k\epsilon/\theta$ and J within practical limits to give the maximum value of f.

Optimum Design

It may be shown from equations (6), (8) and (10) that :—

$$\frac{\partial f}{\partial W}=\frac{m}{3m+1}\cdot\frac{f}{W}$$

$$\frac{\partial f}{\partial H}=\frac{2}{3m+1}\cdot\frac{f}{H}$$

and

$$\frac{\partial f}{\partial P}=\frac{2m}{3m+1}\cdot\frac{f}{P}$$

where P is, for convenience, written in place of $k\epsilon/\theta$.

Thus, the natural frequency f and the frequency range increase with W, P and H for all values of m. That is the power dissipated by the strain gauge W should be as high as possible ; $P(=k\epsilon/\theta)$ should be as large as possible, i.e. the deflection of the coil should be as small as possible consistent with the required recording accuracy. Whilst it pays to increase the field strength H, little is gained by increasing the field beyond the point at which m is fairly large compared with unity, as the natural frequency is then almost independent of H.

Once the strain gauge power dissipation and field strength have been arranged at their convenient maxima and the strain sensitivity at the minimum acceptable, it remains to select the optimum coil dimensions. Clearly, the wire is most effectively used if the length of the coil is large in comparison to its breadth. The ratio of the active to the inactive inertia is then the greatest. The inertia of the inactive portions of the coil (i.e. the top and bottom portions which lie parallel to the magnetic lines of force) may then be neglected and the inactive inertia of the system consists of those of the mirror and the varnish and the coil former or bobbins.

The conditions for the natural frequency to be a maximum will now be derived.

In practice a mirror of the minimum size consistent with satisfactory optical performance is selected and bobbins of the minimum practicable diameter. Then if the total inertia is J, $J=J_a+J_i$.

The wire inertia J_a is very nearly proportional to the number of turns N since the cross-section through the bundle of wires forming a side of the coil is small compared with the breadth of the coil itself.

Thus the inertia may be expressed in the form

$$J_a=\eta+\psi N \quad . \quad . \quad . \quad . \quad (11)$$

where η and ψ are constants.

The resistance of the coil R_G is also proportional to the number of turns N. Thus, equations (6) and (8) may be expressed in the form :—

$$\frac{K(m+1)}{m^{\frac{1}{2}}}=C_1N^{\frac{1}{2}} \quad . \quad . \quad (12)$$

and

$$K^{\frac{1}{2}}(m+1)=C_2N/J^{\frac{1}{2}}$$
$$=C_2N/(\eta+\psi N)^{\frac{1}{2}} \quad (13)$$

where C_1 and C_2 are constants involving the design parameters.

Eliminating K between equations (12) and (13),

$$m(m+1)^2=\frac{C_2^4N^3}{C_1^2(\eta+\psi N)^2} \quad (14)$$

From equation (13),

$$K=\frac{C_2^2N^2}{(m+1)^2(\eta+\psi N)} \quad . \quad . \quad (15)$$

Eliminating K and J between equations (10), (11) and (15),

$$f=\frac{1}{2\pi}\frac{C_2N}{(m+1)(\eta+\psi N)} \quad . \quad (16)$$

Now let f^1 and m^1 be the first derivatives of f and m with respect to N. Then from equation (16) differentiating with respect to N and putting $f^1=0$, f is a maximum when

$$\frac{m^1}{m+1}=\frac{\eta}{N(\eta+\psi N)} \quad . \quad . \quad . \quad . \quad (17)$$

Differentiating equation (14) with respect to N and simplifying,

$$\frac{3m+1}{m}\cdot\frac{m^1}{m+1}=\frac{3\eta+\psi N}{N(\eta+\psi N)} \quad . \quad . \quad . \quad . \quad (18)$$

Eliminating $m^1/(m+1)$ between equations (17) and (18), and simplifying,

$$N=\frac{\eta}{\psi m} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

or the mismatch is equal to the ratio of the inactive to the active inertia. Substituting this value for N in equation (13),

$$m(m+1)^2=\frac{C_2^2}{C_1}\left(\frac{\eta}{\psi^3}\right)^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad . \quad (20)$$

This equation gives the value of m for the optimum frequency response, and thus the values of the suspension rigidity K, the number of turns N, the galvanometer resistance R_G, the appropriate strain gauge resistance mR_G, the natural frequency f and the frequency range of the instrument (zero to $0{\cdot}75f$).

Practical Limitations

In practice a limit is set to the maximum obtainable natural frequency not only by the inertia of the mirror and bobbins but by the electrical resistance of the suspension tapes and by the minimum diameter of wire with which it is practicable to wind the coil.

As the inertia of the moving parts is reduced, the suspension rigidity must also be reduced ; ultimately the electrical resistance of the tapes becomes more important than the reduction of the inertia and the frequency response begins to fall off again. Allowance may readily be made in calculations for the resistance of the tapes. Assuming that they are made from phosphor bronze of specific resistance $12{\cdot}7.10^{-6}$ ohms per centimetre cube and that their breadth is five times their thickness, it may be shown that the resistance of one tape is $7{\cdot}25l^{\frac{1}{2}}/K$ ohms where l is its length in centimetres and K the stiffness in dyne cm per radian.

In making allowance for the resistance of the tapes, R_G is increased to R_{G1} by an amount dependent on the value of K which in the first instance is calculated on the assumption that the tapes resistance is negligible. The new value of m is calculated from equation (9) and that of K from equation (8). If necessary the new value of K is used to give more accurate values of m, K, mR_{G1} and f. The minimum practicable diameter of the wire used in winding the coil is determined by difficulty of handling and the effect of magnetic material in the coil. This generally means that the optimum value of the strain gauge resistance mR_G is too low for satisfactory strain gauges. It is possible to construct strain gauges of sufficiently low resistance which are still capable of dissipating the required heat,

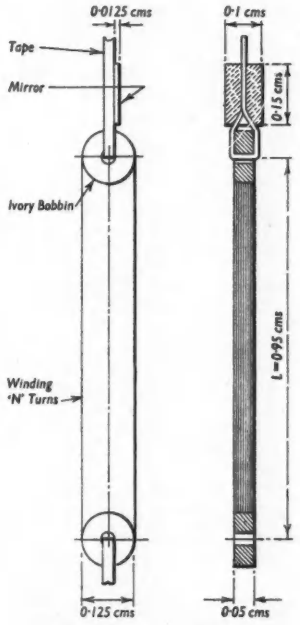

Fig. 1—Galvanometer Element

but this is not generally justified since the analysis shows that the use of a coil carrying more turns of wire than the optimum does not usually involve a serious loss in performance. Moreover, it is desirable to avoid low values of strain gauge resistance since the voltage applied to the bridge is then low and the generation of thermoelectric e.m.f. becomes serious. Furthermore, unduly heavy leads to the strain gauges would be required so as to avoid voltage drop in them. Finally, the theoretical optimum may require so few turns that the coil is mechanically too weak and distorts in use, or alternatively so much varnish is required to strengthen the coil that the inertia is unduly increased and the advantage lost.

Theoretical Performance Curves

A typical coil is shown in Fig. 1 simplified by the omission of flanges on the bobbins. The graphs of Fig. 2 show how the undamped natural frequency, suspension rigidity and strain gauge resistance vary with the number of turns on the coil. The dimensions of the coil are given in Fig. 1. The other parameters are : H=12,000 oersteds, W=0·5W, wire

diameter 0·0025cm (50 S.W.G.) copper. The strain sensitivity is such that a strain of 1/2900 causes a deflection of the writing spot of the galvanometer of 1·5cm (optical lever 28cm).

It is seen from the graphs that, in order to work with a strain gauge of resistance 200 ohms, it is necessary to depart from the optimum number of turns. The optimum number is 10, the natural frequency being 80 c/s. To bring mR_G up to 200 ohms, the number of turns must be increased to twenty-three, the frequency falling off to 68 c/s. The tapes stiffness is then 2 dyne cm per radian.

Practical Case

In practice the use of tapes of stiffness as low as 2 dyne cm per radian presents considerable handling difficulties. A strain gauge dissipating powers as great as 4W has, however, been made. Although this entails even further departure from the optimum number of turns in order to secure the correct degree of damping with a 200 ohm strain gauge, the tapes work out to be considerably more robust. The natural frequency of a galvanometer of the same strain sensitivity as that already considered but working with a 4W strain gauge is theoretically 100 c/s. A galvanometer constructed to the appropriate design fell somewhat short of this. It had a natural frequency of 86 c/s and gave a deflection of 1·2cm with a 28cm optical lever (cf. 1·5cm calculated). The recording range of such a galvanometer is 0 to 65 c/s and the accuracy about $\pm 0{\cdot}13$ ton per square inch (in steel) for static and $\pm 0{\cdot}3$ ton per square inch for dynamic strains.

Coils Without Bobbins

It is practicable, though more difficult, to construct coils in which the bobbins are absent; the bobbins are removed after formation of the coil (e.g. by the use of magnesium which is dissolved away in dilute acid). The coil maintains its shape by virtue of the stiffness of the varnish. Owing to the decrease in inertia these coils give a better performance than those wound on bobbins.

It has been shown[3] that if the inertia of the mirror is ignored the optimum form of the coil is such that a cross-section through it at right angles to the suspension consists of two circles tangential at a point on the axis—like a figure 8. If the inertia of the mirror is taken into account, however, the figure 8 cross-section no longer gives the best performance.

Consider the diameter of the equivalent coil cross-section, i.e. the diameter of the single wire which would have the same mass as the N wires constituting the coil. Let the breadth B of the coil be ϕ times this, i.e.:

$$B=\phi DN^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad (21)$$

where D is the wire diameter.

Then it may be shown that:—

$$\frac{K(m+1)}{m^{\frac{1}{2}}}=C_3\phi N \quad . \quad . \quad . \quad (22)$$

and

$$K^{\frac{1}{2}}(m+1)=C_4\phi^2N^2/J^{\frac{1}{2}} \quad . \quad . \quad (23)$$

where C_3 and C_4 are constants derived from the design parameters, and

$$J=\xi+\lambda N^2(\tfrac{1}{2}+\phi^2) \quad . \quad (24)$$

where ξ and λ are constants for any given mirror, wire material and diameter and length of coil.

It may be shown along the lines of the previous analysis that the natural frequency is a maximum when:—

$$N=\frac{\xi}{\lambda m(\frac{1}{2}+\phi^2)} \quad . \quad . \quad . \quad (25)$$

and

$$m(m+1)^2=\frac{C_4^2}{C_3}\left(\frac{\xi}{\lambda^3}\right)^{\frac{1}{2}}\left(\frac{\phi^3}{\frac{1}{2}+\phi^2}\right)^{6/2} \quad . \quad (26)$$

Thus, for each value of ϕ, the value of m for the maximum natural frequency f may be determined and hence K, N, R_G, mR_G and f.

If the resistance of the suspension is ignored, for each value of ϕ there exists a value of N which makes the natural frequency a maximum, the mismatch m then being equal to the ratio of the inactive to the active components of the coil inertia ξ and $\lambda N(\frac{1}{2}+\phi^2)$, respectively.

It may be shown that

$$\frac{\partial f}{\partial \phi}=\frac{1}{(\frac{1}{2}+\phi^2)(3m+1)}\cdot\frac{f}{\phi} \quad . \quad . \quad (27)$$

Thus $\partial f/\partial\phi$ is positive for all positive values of m, and f increases asymptotically to a constant value as ϕ, the form factor defining the relative width of the coil, is increased.

If the suspension resistance is included, the frequency rises initially, then, as the coil becomes impossibly wide and the suspension impossibly slender, decays to zero. Of more importance practically is the case where mR_G is equal to the minimum convenient value for the strain gauge, e.g. 120 ohms. Since the wire diameter cannot be sufficiently reduced, the turns number is greater than the optimum. The number of turns required for the various values of ϕ is given in Fig. 3. The following values of the design parameters have been taken: strain gauge resistance 120 ohms, magnetic field strength 12,000 oersteds, length of coil 0·95cm, wire diameter 0·0025cm (50 S.W.G.) copper, strain gauge power dissipation 0·5W, inertia of mirror 19.10^{-6}gm cm² (mirror 0·1×0·1×0·013cm, the minimum practicable size). The strain sensitivity is such that a strain of 1/2900 causes a deflection of the writing spot of the galvanometer of 1·5cm (optical lever 28cm). The effect of the suspension resistance has been included.

The curves suggest that a useful working point lies at $\phi=4$; the coil breadth is then 0·045cm. The natural frequency is 127 c/s, 20 per cent below the maximum obtainable. Any smaller value of ϕ would involve a narrow coil unduly difficult to manufacture.

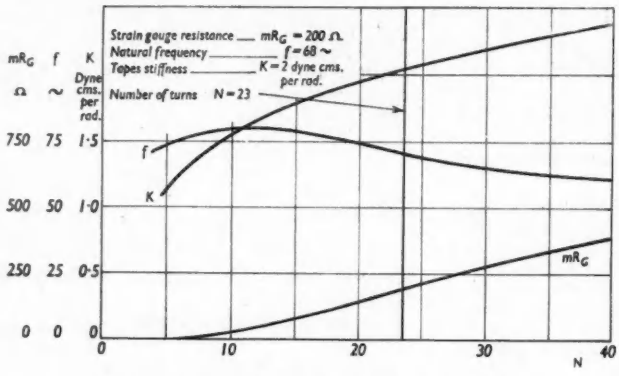
Strain gauge resistance ___ mR_G = 200 Ω.
Natural frequency ___ f = 68 ~
Tapes stiffness ___ K = 2 dyne cms. per rad.
Number of turns N = 23
mR_G f K
Ω ~ Dyne cms. per rad.
750 75 1·5
500 50 1·0
250 25 0·5
0 0 0
f
K
mR_G
0 10 20 30 40
N

Fig. 2—Performance Curves for Coil Wound on Bobbin

Discussion of Results

Natural frequencies are theoretically: (*a*) for the coil wound on bobbins 68 c/s, and (*b*) the coil without bobbins 127 c/s. Thus, although the performance may be expected to fall somewhat short of these figures in practice, there exists a useful range of frequencies over which direct recording of dynamic strains is feasible without any electronic amplification. It is also worth while to use the bobbinless type of coil if possible as the frequency response is so much better than that when the coil is wound on bobbins. The use of 50 S.W.G. aluminium wire would improve the response by 25 per cent for coils wound on bobbins and by almost 50 per cent for formerless coils. The difficulties of soldering would first have to be overcome. These figures relate to a strain gauge power dissipation of 0·5W. When the power rating of the gauges is increased to 4W, the frequency response is further improved.

It has been assumed so far that all four arms of the bridge are equal. It may be shown, however, that if the resistance of the ratio arms is reduced, there is an increase in the maximum obtainable frequency and also in the frequency when the strain gauge resistance is kept at a constant value. The theoretical limit, when the ratio arms have zero resistance, involves an increase of 30 per cent in frequency in the case of a bobbin wound, copper-wire galvanometer working with a 0·5W, 120 ohm strain gauge. The problem of maintaining the stability of the ratio arms becomes serious, however,

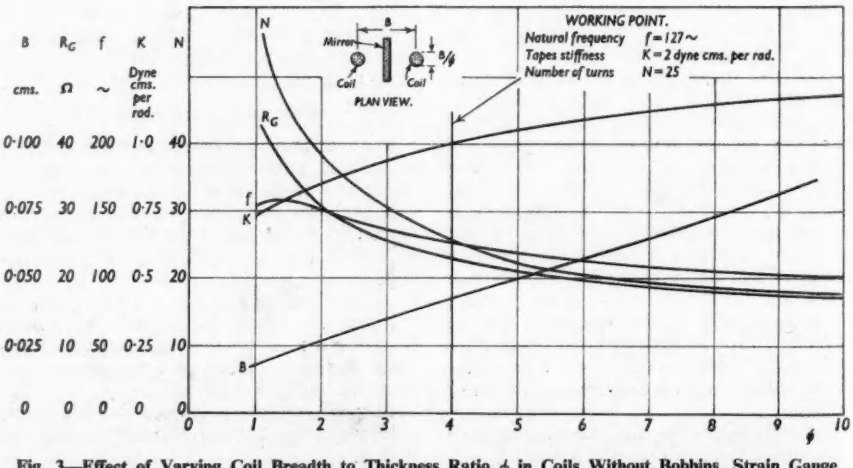

Fig. 3—Effect of Varying Coil Breadth to Thickness Ratio ϕ in Coils Without Bobbins, Strain Gauge Resistance mR_G=120 ohms

as reduction of their resistance means that more heat must be dissipated by them ; and a bridge with four equal arms seems to be the best compromise.

Conclusions

(1) Direct recording of strain gauge signals by means of a galvanometer without recourse to amplifiers is possible both for static and low frequency strains with useful accuracy provided that 1W to 4W can be dissipated as heat by the strain gauge.

(2) An experimental galvanometer has been constructed which records static strains with an accuracy of $\pm 0 \cdot 13$ ton per square inch (in steel) and dynamic strains up to 65 c/s with an accuracy of $\pm 0 \cdot 3$ ton per square inch (in steel).

(3) This galvanometer requires a strain gauge capable of 4W dissipation if these accuracies are to be achieved. (Such a gauge is described in the continuation of this article.)

(4) Theory shows that it should be possible by means of improved galvanometer construction to exceed this frequency range and at the same time reduce the power which must be dissipated by the strain gauge to as low as $0 \cdot 5$W.

References

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[2] A. A. Wells, *J. Sci. Instrum.*, 1950, Vol. 27, page 59.
[3] T. Mather, *Phil. Mag.*, 29 (1890), page 434.

(*To be continued*)

French Locomotive Experiences

By EDWARD H. LIVESAY

(*Continued from page 379, March 12th*)

No. III—DIESEL-ELECTRIC "AUTORAIL" AND COAL TRAINS, PARIS AND LENS

HEAVY coal traffic is carried on between Lens and Paris, 2000-ton trains of 30-ton tare air-braked trucks being the rule, hauled by 4-cylinder compound 2–10–0 engines, and it was arranged that my itinerary should include one of them. Monsieur Leseigneur, Chief of Traction, Nord Division, again offered to drive, and Inspecteur Fillon was to accompany me and give his invaluable help as interpreter of both linguistic and locomotive mysteries, which was very much to my satisfaction. Acquaintance with both of these officials, begun at Calais on my initial run to Paris on "The Golden Arrow," had ripened during our subsequent association into something more than mere formal relationship, so it was only fitting that I should act as host at a very pleasant lunch in Paris before we set off for Lens, which we did as passengers in a fast afternoon train as far as Amiens, the first leg of the journey. The coach in which we travelled, a First Class compartment, eight-wheeler with side corridor, was, I presume, ordinary standard stock of the latest type, and happened to be the last vehicle in the train. I can say without hesitation that it was about the most perfectly behaved railway carriage in which I have ever ridden. Very quiet and smooth-running, it's action was really delightful, the coach seeming to float along like a sledge over snow. Joints were imperceptible and nosing and oscillation entirely absent. Its silky, seductive sway had the dual effect of delighting me and sending my two companions to sleep, from which peaceful siesta I had not the heart to rouse them, however much I wanted to question them about this and that *en route*, as I always did, whoever happened to be with me on these intriguing excursions. The lunch may have been partly responsible but, I am sure, only in minor degree ; the coach's humming flight was at the root of it. The memory of its soothing murmur, luxurious fawn-coloured upholstery and deep pile carpet remains with me still ; it was like being wafted through the pleasant land of France reclining on a feather-bed. It's only rival in good behaviour that I can recall at the moment is the cab of the "Paragon" (Metro-Vick's appellation, and an apt one), C. and N.W.R. diesel-electric on which I rode between Chicago and Milwaukee over a decade ago.

While my companions slept, I pondered, my thoughts going back, by association of ideas, to a run I had taken to Strasbourg a few days before, during which one stretch had been covered in a coach running on twenty pneumatic-tyred wheels. I had expected this to provide the very ultimate possibility of luxurious travel on rails, but I am obliged to admit that promise did somewhat outrun performance ; it was good, granted, but not so good as anticipated ; it fell short of perfection. Lolling in that softly padded compartment, gliding smoothly over the rails, I could not help wondering ; if an ordinary steel-tyred coach could run so sweetly, where was the justification for the cost and complication of a score of rubber-shod wheels which, when all was said and done, failed to give a result in any degree superior to that I was experiencing with a metal-soled vehicle ? I still ask myself that question and believe that the reader can give the appropriate answer without prompting. This conclusion was confirmed later by an official of another division of the S.N.C.F., over which the Michelin production did not operate, whom I approached for an independent ruling ; he was decided in his opinion that the game was not worth the candle. However, all this will come into another article.

Some credit should be given to the track for the good riding of this steel-wheeled coach ; it has been largely relaid since the end of the occupation, during which it deteriorated, to be further damaged by bombing and so forth before and after the invasion. This applies to most of the routes over which I travelled in N.E. and Central France ; I could find very little the matter with the permanent way. Possibly I am wrong, but the sleepers appeared to be placed closer together than in Britain, though the wood did not seem so good, nor always creosoted. Flat-bottomed steel is used, bolted to the sleepers.

At Amiens, one of the chief towns on the way to Lille, we left our luxurious coach for the austerity but greater interest of the cab of a three-car diesel-electric "autorail." These are used extensively on the S.N.C.F. as "feeders" to the lengthier trains, and to serve intermediate stations at which the latter do not stop. I had asked that a brief run with one of them might be arranged. It is illustrated in Fig. 1, which shows it standing in the Gare du Nord, and here I am tempted to stray into æsthetics. Apart from the train, the neatness of which will attract the reader's attention, what is it that is sure to strike him ? Probably the air of brightness, grace and cleanliness of the station—all of these features totally lacking in the average British terminus. Compare it with London stations, such as —— but I haven't the heart to name it ! Could any station be dirtier or more depressing than —— but again loyalty to my native land spikes my guns. The reader will guess which one I refer to, anyway. I used to enjoy wandering about Parisian termini ; yes, positively enjoy it ! The whole atmosphere was so novel—the spacious brightness of them—the cleanliness—particularly the cleanliness. It was pleasant to sit at a little round table off the Concourse with a Martini or cool "Pils" before me—*cool* is underlined—and watch the bustling throng swirling round. Who but an escaped lunatic would ever think of enjoying himself at a London terminus, such as —— yes, that's the one I mean ; or ——, which is even worse ! Think of —— in Manchester ; or —— in Glasgow—but in Heaven's name, let us pass on ! Why must we be so dingy, so dirty, so smelly ? Surely we could clean and brighten up our stations a little, even if we are too "broke" to pull them down and rebuild them ? But the whole thing is depressing—let us get on to something more attractive, such as the design and performance of an "autorail," the leading particulars of which follow :—

The motor-coach carries a twelve-cylinder "V"-type Maybach direct-injection, four-

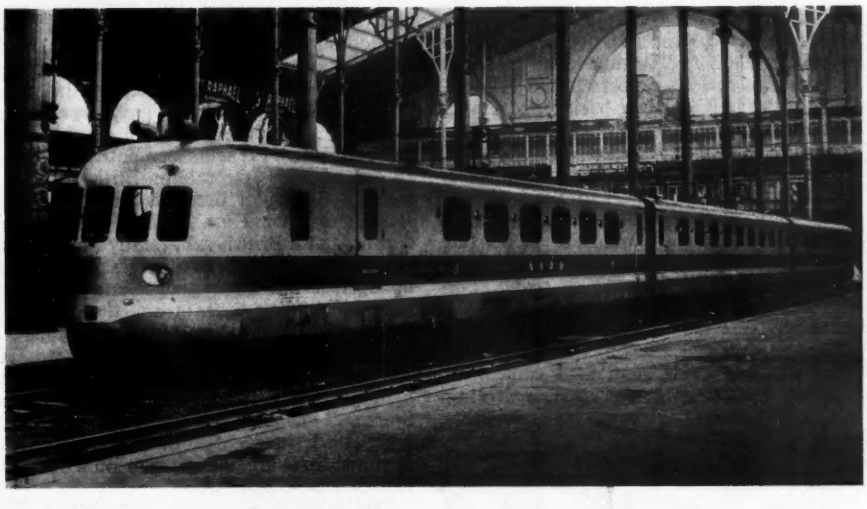


Fig. 17—Diesel-Electric "Autorail" Train in the Gare du Nord

stroke engine direct-coupled to a generator ; the cylinders are 160mm by 200mm developing 410 h.p. at 1400 r.p.m. The 800V, 336kW generator has a continuous output of 420A, supplying current to two nose-suspended, self-ventilating motors connected in parallel, driving the power bogie axles through 13/5 reduction gears. The diesel engine is mounted on a sub-frame with "Silentbloc" supports, and is gravity fed from two tanks each of 350 litre capacity. The auxiliary generator is a 110V, 8kW, 1350 r.p.m. machine.

The controller has six notches and is fitted with a dead-man's handle ; air brakes are fitted and an electrically-driven compressor supplies a reservoir carrying a maximum pressure of 118 lb. At 62 m.p.h. the train can be brought to a stand in 360 yards. A Flaman recorder and speed indicator is fitted, and a coke-fired boiler supplies heat, the water being circulated by an electrically-driven pump.

In running order the motor-coach weighs 52 tons and loaded 57 tons. Its maximum speed is 93 m.p.h. (Figs. 17 and 18.)

Leaving Amiens at 3.48, acceleration was rapid, 80km being attained in a mile or so, recorded by the Flaman right beside the driver. This invaluable tell-tale is found on every type of French locomotive running over the open road ; would that this were so in Britain, too. The riding was very good ; there was no vertical movement whatever, and what little of the horizontal was short and quick, in no way objectionable. For several miles out of Amiens the track is more or less level over the 25km to Buire-sur-Ancre, where a stiff rise begins, extending to a peak at Achiet. A gradient profile of the Amiens/Douai section will be found in Fig. 16 on page 378 *ante*. We swept through Lamotte at 3.53—6km in 5 min—to a stop at Corbie, 4.01—15km in 13 min—leaving again at 4.02. There was no vibration from the engine, nor obtrusive noise, and a quotation from my notes says : "Action over crossings and switches perfect—imperceptible." Albert, well up the long climb to Achiet, part of it as steep as 1 in 200, was reached at 4.16, departure being at 4.17 ; continuing upward, we stopped at Achiet, the summit, at 4.31. The 50km from Amiens had been covered in 43 min, with two stops inclusive, at an average of 42 m.p.h. We were well in the zone of the first war now, and many nostalgic names were noted *en route*. Passing Beaucourt, my attention was sympathetically directed to the Canadian war memorial, the impression throughout the tour evidently being that, as I came from Canada, I must be a Canadian, a delusion of which I tried to disabuse my kind hosts, without much success. *Civis Britannicus sum*, and Canadian only by adoption.

From Achiet, left at 4.33, the line has a descending tendency through Arras, arr. 4.47 O.T., past the Great War memorial, the speed often touching the 100km mark, to Douai, where the arrival time was 5.11. Here we detrained, to await the arrival of another diesel "autorail" which was to take us over the branch line to Lens. I filled in the time by writing a card, which I posted in a box marked "Correspondence pneumatiques," under the impression this meant "Air mail." I was undeceived by Fillon, who explained, amid laughter, it was for letters shot through a pneumatic tube to the sorting office. A "derangement of epitaphs," but how could I, a stranger in a strange land, be expected to guess that ? Boarding the other diesel, smaller and of a slightly inferior pattern, but, nevertheless, very effective, we set off on the last lap of the journey, through flat terrain dotted with slag piles, past another monument at Notre Dame de Lorette, to a stand at our destination, the typical coal-mining town of Lens, at 5.21. Not having the appropriate figures of the final short stretch from Douai to Lens I cannot include this in the overall summary, but the 58 miles from Amiens to Douai had taken 103 min, inclusive of half-a-dozen stops, which makes the average speed over this section 33 m.p.h., fairly representative of the trip as a whole, and of the work done by an "autorail." It struck me as being efficient and comfortable and an admirable auxiliary to through trains serving large centres.

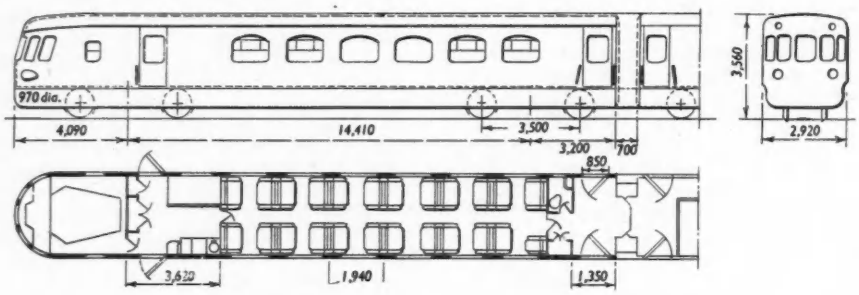


Fig. 18—Outline and Leading Dimensions of "Autorail" Train

"*Rafraîchissement*" and supper followed, Leseigneur presiding this time, after which he suggested we had better get to bed, as we should have to be up at 1 a.m., our train leaving an hour or so later ; the enginemen's hostel was to be our dormitory. The shed, with hostel near by, being a couple of miles away, a big four-cylinder compound 4–8–4 tank engine was boarded in the yard to take us there and quite an impressive machine it was. The cab, roomy and well-ventilated, with side windows and a sliding roof, gave a good look-ahead in both directions, and the completeness of the equipment, seeing that this was only a tank-engine, was striking ; every possible indicative gauge featuring the back-plate, clearly visible in the electric light standard on French locomotives, which I often wish was the rule on British engines, too. A feeling of tiredness steals over me sometimes when I am hurtling through the darkness in a British cab, faintly illuminated by the feeble glimmer of an oil lamp cuddling up against the water gauge, and by intermittent blinding glare from the fire-door when this happens to be open, which it seldom is when I particularly want to see something. An Austin "7" has electric light—so has a French tank engine—but a Stanier "Pacific" has not, in this year of grace 1953, in an age of electricity. The farthing dip is an anachronism on a modern locomotive—out upon it !

The cab was somewhat dirty, as is only to be expected when such poor, dusty coal has to be used ; briquettes were stacked at the back for use when standing, or in the shed. It is remarkable that French locomotives do the fine work for which they are noted handicapped by poor fuel. Needless to say, the ubiquitous Flaman recorder was in evidence.

The hostel was an admirable caravanserai, laid out in every way tending to the enginemen's convenience and comfort, with large, bright, tiled rooms, attractive and—need I say ?—clean. I was shown to a comfortable bedroom, turning into a bed with spotless linen, and told the caller would wake me at 1 a.m. He did ; I dressed with alacrity and with annoyance on noticing I had left the impress of a dirty head on the snowy pillow. If it was like that even before the run started it was easy to guess what would be its condition at the finish ! Descending, I discovered Leseigneur at the kitchen stove in a pleasant aroma of "Nescafé" and "hot dogs" ; thence through the darkness to the shed—and what a shed ! A big building with an arched roof rivalling St. Pancras, flooded with golden light from rosy neon lights shining down on glittering engines standing like show-pieces over the pits ; not a thing out of place, order and cleanliness evident from one end to the other. I looked at it admiringly and thought of the average shed in Britain—the contrast was complete. The only criticism I had to make was that the shed was open-ended ; in winter it must be a Cave of the Winds, but if I remember aright it was new ; possibly it will be closed in ultimately. Yes, I think the shed was a post-war erection, so perhaps it is unfair to compare it with the average British sheds, most of which seemingly were built in Stephenson's day. But it was almost as pleasant to be in as in a Parisian terminus, even though it was the middle of the night ; my vitality might be low but my admiration was high and glowed like the neon lights overhead. I would have liked to look round this attractive shed, but Leseigneur, Fillon and the big four-cylinder compound 2–10–0 were all ready and waiting, so I joined them ; the next article will describe the run to Paris—or Le Bourget, to be exact—with a 2000-ton train.

(To be continued)

Nuclear Reactor at Pennsylvania State University

THE U.S. Atomic Energy Commission has approved the allocation of fissionable material as fuel for a nuclear reactor to be built by Pennsylvania State University. This low-power "swimming pool" reactor will be operated for nuclear research and for the training of students. It is the second privately owned reactor in America for which the A.E.C. has authorised the use of nuclear fuel. The first pile was built by the Consolidated University of North Carolina and began operation last September. The cost of construction and operation of the scheme will be borne by the university, without financial assistance from the Commission. The reactor will operate at a power level of 100kW. It will be cooled and moderated with ordinary water, and will use enriched uranium fuel. The fuel elements will be suspended in a pool of water sufficiently deep to serve as a shield against the radiation produced. A similar "swimming pool" plant, known as the Bulk Shielding Test Reactor, has been in operation at the Oak Ridge National Laboratory since 1952, and has proved to be safe to operate and easy to maintain.

The actual transfer of fissionable material required for the reactor will occur after the A.E.C. has given final approval to the health, safety and security aspects of the completed reactor.

High-Tensile Steel Bolts for Structural Joints

(By Our American Correspondent)

No. I

In the last few years, the use of high-tensile steel bolts for structural joints in place of rivets has found a number of interesting applications in the United States, and the procedure involved has now been standardised with the approval of the American Research Council on Riveted and Bolted Structural Joints. This article deals with the properties of the bolts, nuts and washers employed, describes a representative fastening method and outlines a number of applications to railway bridges and other structures.

THE assembly of structural joints using high-strength steel bolts is a relatively new technique and results directly from the extensive research on fabricated joints which has been conducted within recent years. The use of commercial black or unfinished bolts in loose-fit holes is economical and has been common practice in America for years, but such bolts cannot be sufficiently tightened to prevent slip under working shear loads. Accordingly, their use is confined to secondary connections where slip is unimportant; elsewhere rivets are specified, to secure a better filling of the holes.

To drive tight rivets it is necessary first to bolt the parts into tight contact; high-strength bolts have been used for years for this purpose, as the force required would strip the threads of common bolts. As riveting progresses these bolts are replaced, one by one, with rivets. In the procedure to be discussed, high-strength bolts are used in all the holes. Loose-fit holes are retained for economy in assembling, but the nuts are driven up with power spanners to provide more clamping force than is possible with rivets, so that slip at working loads is not possible in view of the high friction produced between the joined members. The bolts are made of carbon steel, heat-treated for strength, and a hardened washer is placed both under the bolt-head and the nut, to permit the development of the high torque required without scoring the connected material.

To promote extensive and unified research into the subject of riveted and bolted structural joints, representatives of various groups interested in the behaviour of such joints in structures met in New York City on January 15, 1947, and organised The Research Council on Riveted and Bolted Structural Joints. The Council was formed because it was generally recognised that existing practice in the design of riveted and bolted connections had been empirically developed from experience, and that many of these practices were not supported by definite experimental data. The objective of the Council is to sponsor extensive research to promote the safer and more economical design and construction of metal structures.

In the past few years, high-strength bolts have been substituted for rivets in an increasing number of structures for commercial multi-storey buildings. To meet an increasing demand, there is now available from such firms as the Bethlehem Steel Company a range of sizes of heat-treated, high-strength carbon steel bolts specifically designed for this type of work. These bolts, together with the nuts and washers, conform to the requirements of the A.S.T.M. Specification A-325, covering "Quenched and Tempered Steel Bolts and Studs with Suitable Nuts and Washers." This specification requires a full heat-treatment, quench and temper, and in the usual structural diameters calls for mechanical properties as shown below.

Bolt size (in)	Stress area (sq in)	Threaded bolt test specimens	
		Minimum ultimate load of bolts and proof load of nuts (lb)	Minimum proof load of bolts (lb)
½	0·2256	27,000	19,180
⅝	0·3340	40,000	28,390
¾	0·4612	55,300	35,970
1	0·6051	72,600	47,200

The chemical composition specified for the bolts is such as to require the use of electric furnace or basic open-hearth steel. The nuts are required to meet a proof load equivalent to the minimum ultimate load of the bolts, as shown in the above table. The washers have to be hardened to a Rockwell "A"-68/75 value and, if carburised, they must have a minimum depth of case of 0·015in.

As a result of extensive laboratory work and field tests on structural joints fastened with high-strength bolts, the Research Council on Riveted and Bolted Structural Joints has approved a "Specification for the Assembly of Structural Joints Using High-Tensile Steel Bolts." This specification was published in January, 1951, and covers the recommended practice for the fabrication of structural steel forming rigid joints using high-strength steel bolts where initial tension in the bolt body is depended upon to resist shear load through friction at the faying surfaces. Until further tests dictate otherwise, such bolts are to replace rivets of the same nominal diameter. The bolt dimensions shall conform to the current requirements for "Regular Semi-finished Hexagon Head Bolts" of the American Standards Association, except that the radius of fillet under the bolt head shall not be less than $^1/_{64}$in for sizes ⅝in and under, $^1/_{32}$in for sizes over ⅝in to 1in, inclusive, and $^3/_{64}$in for sizes over 1in. The nut dimensions shall conform to the current requirements for "Heavy Hexagon Semi-finished Nuts" of the American Standards Association, and the washers shall be flat and smooth, and their dimensions shall conform to the following table :—

Bolt size (in)	Inside diameter (in)	Outside diameter (in)	Nominal thickness (in)
½	⅝	1¼	0·109
⅝	¾	1½	0·134
¾	⅞	2	0·148
⅞	1	2¼	0·165
1	1⅛	2½	0·165
1⅛	1¼	2¾	0·165
1¼	1⅜	3	0·165

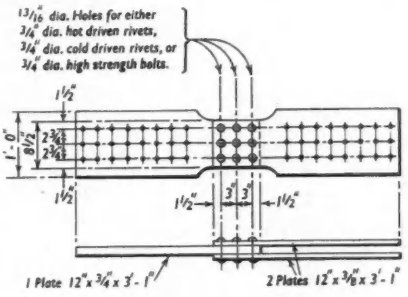
Where clearance makes it necessary, washers may be clipped on one side at a point not closer than ⅞ of the bolt diameter from the centre of the washer. Where bearing faces of bolted parts are not parallel, bevelled washers shall be used to compensate for any lack of parallelism. The specification requires, furthermore, that all nuts shall be tightened to give the bolt tension values listed in the following table :—

Bolt size (in)	Required bolt tension (lb)	Equivalent torque (lb-ft)
½	11,500	100
⅝	17,300	180
¾	25,600	320
⅞	32,400	470
1	42,500	710
1⅛	50,800	960
1¼	64,500	1350

The above values of required bolt tension are equal to 90 per cent of the specified minimum elastic proof load of the bolt. The values of equivalent torque were developed on the basis of 0·0167 lb-ft per inch of bolt diameter per lb of tension, assuming non-lubricated bolts and nuts.

Laboratory Tests

A number of investigations, which were conducted by various laboratories in America within recent years to determine the static and fatigue strength of riveted joints connecting steel plates, have shown clearly that the rivets, both hot and cold-driven, do not completely fill the holes in these plates. It is generally agreed that the load, in most cases, is transferred from one plate to the other by friction between the plates resulting from the clamping action of the rivet heads. The magnitude of the clamping force exerted by the heads of various lengths of rivets was investigated by Professor Wilson of the University of Illinois over twenty years ago, and he found that hot-driven button head rivets had an initial tension equal to at least 70 per cent of the yield strength of the rod from which the rivets were made. He further found that the initial tension or clamping force increased slightly with an increase in the grip of the rivet. The fact that the load-carrying capacity of a structural joint depends upon the magnitude of the friction between the plates resulting from the clamping forces of the rivet heads and not upon the degree of filling the holes by the shank of the rivet, indicated to Professor Wilson that a structural fastener, such as a high-strength bolt, capable of exerting a high clamping force, would be superior to a rivet. Fatigue tests, which he conducted on structural joints fastened by high-strength bolts appreciably smaller than the holes in the plates, supported this hypothesis, provided that the nuts were screwed up to give a high tension in the bolts. Important information on the relative static and fatigue strength of joints fabricated with different fasteners resulted from an investigation[1] conducted recently under the sponsorship of the Industrial Fasteners Institute of America. The purpose of this investigation was to determine the relative effects of various fasteners on the fatigue strength of three groups of structural joints, identical except for the type of fastener. The three fasteners investigated were hot-driven rivets, cold-driven rivets and high-strength bolts.



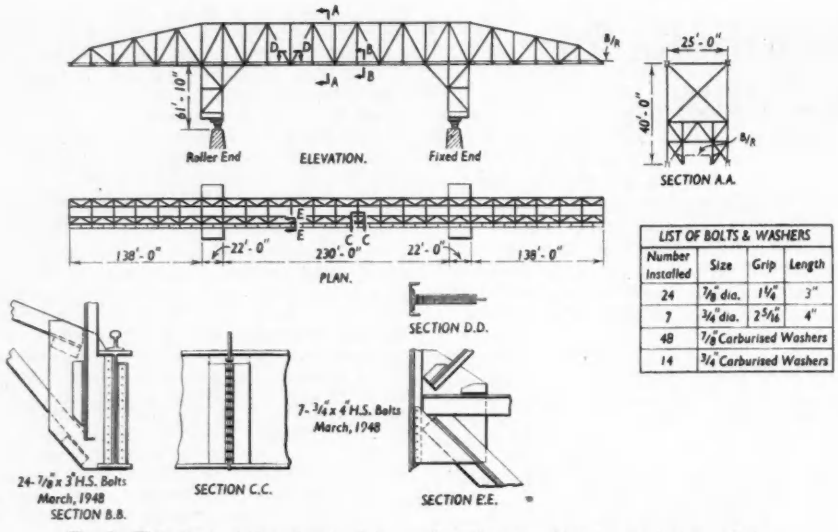
Area : Tension ... 4·50 square inches
Shear ... 7·90 square inches
Bearing ... 5·06 square inches
Tension : Shear : Bearing ratio, 1·00 : 0·57 : 0·89

Fig. 1—Structural Joint Used for Fatigue Tests

The detail of the structural joints used for these comparative tests is shown in Fig. 1. It consists of a ⅜in centre plate and two ⅝in outside plates, with the nine ¾in diameter fasteners arranged in a square pattern. The plate material met the requirement of the A.S.T.M. Specification A7 with the following average physical properties :—

Yield strength	34,400 lb per square inch
Ultimate tensile strength	62,700 lb per square inch
Elongation in 2in	28·6 per cent
Modulus of elasticity	29,600,000 lb per square inch

The structural joints were tested in reversed cycles of stress varying from a tensile stress of about 20,000 lb per square inch on the net section to a compressive stress of about 20,000 lb per square inch by means of a fatigue testing machine operating at a speed of 180 cycles per minute. A total of twenty-four joints were fabricated and tested in fatigue under a complete reversal of load. Nine of the joints were fabricated with cold-formed, cold-driven rivets. Six of the specimens were fastened with hot-driven rivets, and high-strength bolts, having a yield point of approximately 85,000 lb per square inch, were used to fabricate the remaining nine specimens. The latter bolts were torqued to produce a high clamping force. Each specimen was subjected to complete reversals of load until failure. The average values obtained for



LIST OF BOLTS & WASHERS			
Number Installed	Size	Grip	Length
24	7/8" dia.	1 1/4"	3"
7	3/4" dia.	2 5/16"	4"
48	7/8" Carburised Washers		
14	3/4" Carburised Washers		

Fig. 2—Field Test of High-Tensile Bolts on Ore Unloading Bridge at Ashtabula, Ohio

each type of fastener are shown in the following table :—

Fatigue Strength of Fabricated Joints

Type of fastener	Fatigue strength at 2,000,000 cycles at full reversal
Cold-driven rivets	14,700 lb per square inch
Hot-driven rivets	15,820 lb per square inch
High-strength bolts	17,200 lb per square inch

These results were of particular interest to structural engineers connected with American railways, but it was realised that even though the laboratory tests indicated that high-strength bolts were superior to rivets, it would still be necessary to determine if the bolts would stay tight in railway bridges under normal operating conditions (where the members were subjected to considerable vibration) before their use would be accepted. Accordingly, the research staff of the Association of American Railroads arranged with several of the American railway companies to replace rivets with high-strength bolts at particular joints where trouble had been encountered in keeping rivets tight[2].

Railway Bridge Installations

The general procedure which was followed in making the field test installations of the bolts was to remove the rivets at the selected positions by either knocking or burning off the rivet heads, backing out the rivets and then cleaning the steel surface around the hole. The high-strength bolts were installed with hardened washers placed underneath the head and the nut. The bolts were then tightened to the approximate clamping force by means of a simple ratchet spanner. The correct amount of torque to develop the desired bolt tension or clamping force was obtained subsequently by the use of a torque spanner, making sure that the torque reading was taken when the nut was still turning on the bolt, since there is a considerable difference between the static and sliding coefficient of friction. The torque used for the installation of all the test bolts in the field produced a unit stress on the mean thread area of the bolt equal to about 85 per cent of the yield strength of the bolt or about 72,000 lb per square inch. The high-strength bolts were installed with only the hardened washers under the head and nut, and no lock washers or burring of the threads were used to keep the nuts from turning. The nuts were kept on the bolts entirely by the friction resulting from the high clamping force. The bolts, washers and nuts, however, were covered with a black paint upon completion of the installation to facilitate, during future inspections, the detection of any loosening of the nuts.

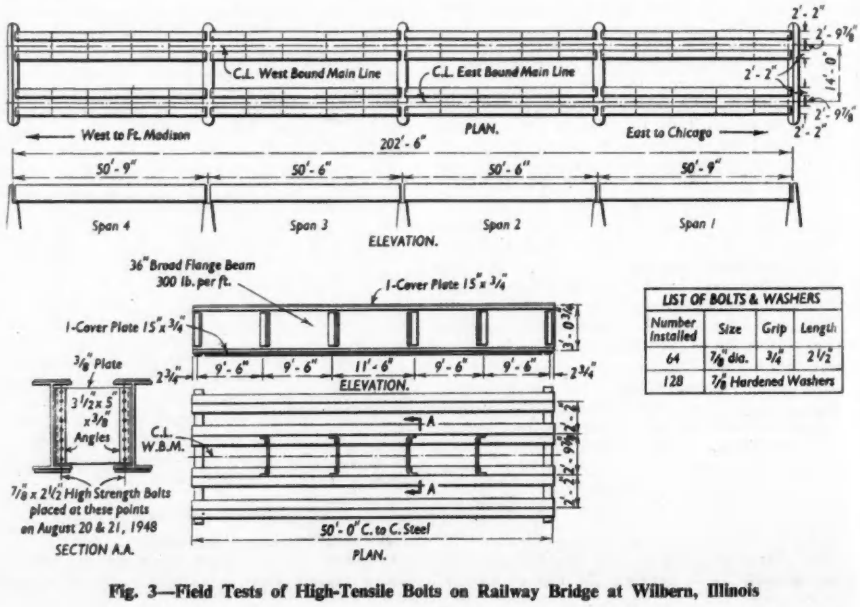
The first field installation was in the ore unloading bridge of the Pennsylvania Dock Company at Ashtabula, Ohio, and a line diagram of this structure is shown in Fig. 2. The structure carries the machinery used in unloading iron ore from Great Lakes barges. The ore unloading machinery is used continuously during the navigation season so that the structure is subjected to a large number of cycles of stress. The positions of the test installations of the high-strength bolts are shown in the detailed sections. These particular joints were selected as considerable trouble had been encountered in the past in keeping their rivets tight, and it had been necessary to re-drive the rivets every year at considerable expense.

Twenty-four $\frac{7}{8}$in diameter bolts were installed at the connection of the trolley stringers to the hanger gusset plate, as shown in sections B-B and elevation C-C. The bolts were tightened to a torque of 470ft-lb with the torque spanner to produce a unit stress of 70,000 lb per square inch on the mean thread area and a clamping force of 32,000 lb. The $\frac{7}{8}$in diameter bolts installed at the gusset plate connection to the post, shown in sections D-D and E-E, could not be properly tightened with the torque spanner at the time as the available socket attachment on the spanner would not fit the bolts. Therefore, the bolts were temporarily tightened to the estimated torque with an ordinary spanner. The bolts were inspected two months after they were installed and all the bolts appeared to be tight as there was no evidence of rust or working of the members. However, when the $\frac{7}{8}$in diameter bolts at sections B-B and C-C were checked with the torque spanner, it was found that a few of the bolts had lost some of their original torque. All of the bolts at this joint were retightened to the original torque. The $\frac{7}{8}$in diameter bolts at sections D-D and E-E were checked with the torque spanner, which had, in the meantime, been fitted with a new socket attachment, and it was found that they had retained their full clamping force. The bolts were again inspected eighteen months after they were installed or after about two years' use by the ore unloading machinery, and no evidence could be found of cracked paint, rust or any other sign that the bolts were loose or the members slipping. A check with the torque spanner indicated that the bolts were retaining their full clamping force. The fact that a few of the $\frac{7}{8}$in diameter bolts had lost some of their clamping force shortly after being installed was very disconcerting, but it is considered possible that the tightening of adjacent bolts loosened those already tight. This appears to be borne out by the fact that the bolts stayed tight after they were retightened during the first inspection.

The double-track bridge of the Atchison, Topeka and Santa Fe Railway at Wilbern, Illinois, shown in Fig. 3, consists of single-track beam spans under the two tracks carrying high speed passenger and freight trains. Each span consists of two 36in broad flange beams per rail having an overall length of 50ft. The beams are reinforced with diaphragm plates and angles at the fifth points. High-strength bolts were used to connect the $\frac{3}{8}$in plates to the stiffener angles in the centre row of diaphragms of the west span. The bolts were tightened to the estimated torque by means of a ratchet spanner. Several of the bolts in each diaphragm were then checked by marking the position of the nut, backing off the nut and then tightening the bolt with the torque spanner to the required torque. It was not possible to check all the bolts with the torque spanner on account of the limited space between the beam flanges, but those checked indicated that the required torque was being applied satisfactorily with the ratchet spanner.

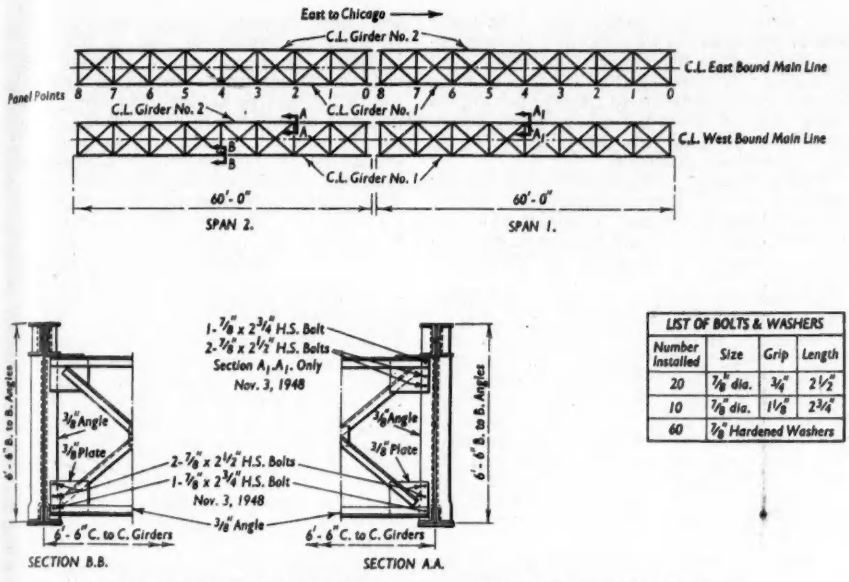
The bolts in this bridge were inspected eight months after their installation, and there was no evidence of cracked paint, rust or slipping of the diaphragm plates on the angles. Several of the nuts were marked to show their relative position with the bolt and then backed off a full turn. The nuts returned to their original position when retightened to the required torque, indicating that the bolts were retaining their full clamping force. The bolts were again inspected thirteen months after their installation without any evidence of rust, cracked paint or slipping. A check of the accessible bolts with the torque spanner indicated that they were staying tight.

The double-track bridge of the Chicago and North-Western Railroad at Beaver, Iowa, shown in Fig. 4, consists of four single-track deck girder spans having a length of 60ft overall of girders. Considerable trouble is usually encountered with this kind of bridge in maintaining



LIST OF BOLTS & WASHERS			
Number Installed	Size	Grip	Length
64	7/8" dia.	3/4"	2 1/2"
128	7/8" Hardened Washers		

Fig. 3—Field Tests of High-Tensile Bolts on Railway Bridge at Wilbern, Illinois


East to Chicago
C.L. Girder No. 2
C.L. East Bound Main Line
Panel Points 8 7 6 5 4 3 2 1 0 8 7 6 5 4 3 2 1 0
C.L. Girder No. 2
C.L. Girder No. 1
C.L. West Bound Main Line
C.L. Girder No. 1
60'-0"
SPAN 2.
60'-0"
SPAN 1.
1-7/8" x 2 3/4" H.S. Bolt
2-7/8" x 2 1/2" H.S. Bolts
Section A1 A1 Only
Nov. 3, 1948
3/8" Angle
3/8" Plate
6'-6" B. to B. Angles
2-7/8" x 2 1/2" H.S. Bolts
1-7/8" x 2 3/4" H.S. Bolt
Nov. 3, 1948
3/8" Angle
6'-6" C. to C. Girders
SECTION B.B.
SECTION A.A.

LIST OF BOLTS & WASHERS			
Number Installed	Size	Grip	Length
20	7/8" dia.	3/4"	2 1/2"
10	7/8" dia.	1 1/8"	2 3/4"
60	7/8" Hardened Washers		

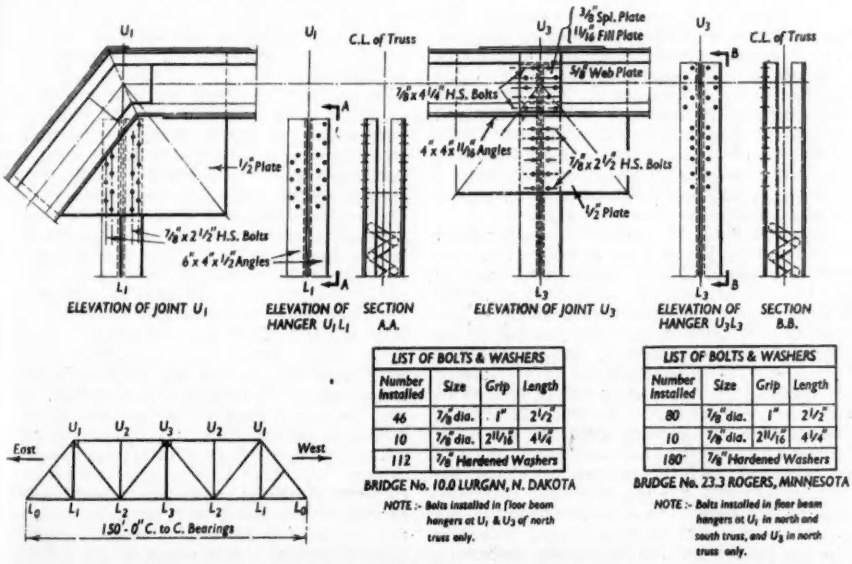
Fig. 4—Field Test of High-Tensile Bolts on Railway Bridge at Beaver, Iowa

tight rivets connecting the lateral plates to the stiffener angles of the girders on account of the differential in girder deflection resulting from the rolling of the locomotives. In this particular bridge the loose rivets had previously been replaced with standard bolts and spring washers. The standard bolts became loose within a year but the spring washers had retained sufficient pressure to prevent the nuts from backing off entirely of the bolt. The standard bolts and spring washers were replaced with high-strength bolts and hardened washers at the positions indicated and were then tightened to the required torque as indicated by the torque spanner. The bolts in this bridge were inspected ten months after their installation and no evidence of cracked paint, rust or slippage of the plates on the stiffener angles could be detected. The torque spanner was then used to check each bolt and it was generally found that the nuts on two of the bolts at each connection would move at a torque slightly below the tightening torque while the nut on the third bolt required a far greater torque before turning. It is believed possible that this difference in torque results from not tightening the bolts for a second time when they were installed, as the tightening of the last bolt could relieve the clamping force in the other two bolts.

It was considered desirable to make several field test installations of high-strength bolts in bridges which are subject to temperatures of at least −40 deg. Fah. One of these is the bridge at Lurgan, North Dakota, of the Great Northern Railway, which is shown in Fig. 5. This bridge is a single-span through truss carrying a single track. The high-strength bolts are situated in one end floor beam hanger and one centre floor beam hanger of one truss at the upper chord gusset plate. Of the fifty-six bolts in service in the structure, thirty-three were checked with a torque spanner about a year after installation to determine whether they had lost tension. The number of bolts and the torque at which these bolts started tightening are as follows: one at 270ft-lb; one at 300ft-lb, eight at 330ft-lb; three at 360ft-lb; six at 390ft-lb; five at 420ft-lb; four at 450ft-lb, and five which did not turn at 470ft-lb. The end floor beam hanger has bolts on both the inside and outside of the member. It is interesting to note that the five bolts which did not tighten under a torque of 470ft-lb are all on the outside of this member. The other two bolts which were checked at this point turned at 450ft-lb. The inside of the same member did not have a bolt that did not tighten at less than the 470ft-lb, the range being from 300ft-lb to 420ft-lb. The outside only of the centre floor beam was bolted, and at this point the results were similar to the inside of the end floor beam, the torques at which the bolts started tightening varying from 270ft-lb to 450ft-lb. It is assumed that the bolts which were not tightened at this inspection will fall into the same pattern as those that were checked; therefore, they were left undisturbed to see if there was any progressive loss of tension. Part of the undisturbed bolts will be checked at a later inspection.

Another cold climate field test is being conducted on the bridge of the Great Northern Railway at Rogers, Minnesota, which is identical structurally to the bridge at Lurgan. The high-strength bolts were placed in an end floor beam hanger and centre floor beam hangers on one truss and the end floor beam hanger on the other truss. The bolts were used to frame the floor beam hangers into the gusset plates at the top chord. Of ninety bolts in service in this bridge forty-six were checked with a torque spanner about a year after installation to determine if they had lost any of their tension. All of the bolts at one end floor beam hanger and half of the bolts at the centre floor beam hanger were checked. Of the bolts checked, one bolt started tightening at a torque of 360ft-lb, four at 420ft-lb, two at 450ft-lb, and seven at 470ft-lb. The remaining thirty-two bolts checked did not tighten further when the 470ft-lb torque was applied. No appreciable difference could be seen in the bolts on the inside of the hanger and those on the outside. It is interesting to compare the bolts in this structure with those in the bridge at Lurgan. The two bridges are identical in all details, were erected in the same year, are subject to similar climatic conditions and carry the same rail traffic. The bolts in the structures were put in under the same conditions by the same workmen, and yet in the bridge at Lurgan approximately 75 per cent of the bolts have lost an average of 30 per cent of their tension, while in the bridge at Rogers 15 per cent of the bolts have lost only about 10 per cent of their tension.

The high-strength bolts installed in all of these bridge structures have been inspected periodically and, after five years, have generally been found to retain their full clamping force. In the meantime, the rivets in similar joints on the same structures, sometimes situated at the other end of the same member, have continued to work loose. Some bolts were installed in jagged holes which had become enlarged as a result of the frequent backing out of loosened rivets. Wherever two hardened washers were placed under the head and nut of these bolts, to prevent deflection in the enlarged holes, the bolts have retained their full clamping force. While, in general, the bolts used in this work were tightened to develop a tensile stress on the mean thread area equivalent to approximately 85 per cent of the specified yield strength, the bolts in several of the joints were deliberately tightened well beyond the yield strength. This excessive amount of prestress has not appeared to be harmful; the bolts so tightened have been functioning satisfactorily for five years without exhibiting any visible evidence of damage or impaired clamping force.



LIST OF BOLTS & WASHERS			
Number Installed	Size	Grip	Length
46	7/8" dia.	1"	2 1/2"
10	7/8" dia.	2 11/16"	4 1/4"
112	7/8" Hardened Washers		

BRIDGE No. 10.0 LURGAN, N. DAKOTA

NOTE:- Bolts installed in floor beam hangers at U_1 & U_3 of north truss only.

LIST OF BOLTS & WASHERS			
Number Installed	Size	Grip	Length
80	7/8" dia.	1"	2 1/2"
10	7/8" dia.	2 11/16"	4 1/4"
180	7/8" Hardened Washers		

BRIDGE No. 23.3 ROGERS, MINNESOTA

NOTE:- Bolts installed in floor beam hangers at U_1 in north and south truss, and U_3 in north truss only.

Fig. 5—Field Tests of High-Tensile Bolts on Railway Bridges at Lurgan, North Dakota and Rogers, Minnesota

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[1] "Exploratory Fatigue Tests of Bolted Structural Joints," Munse and Wilson, Report to Research Council on Riveted and Bolted Structural Joints, Univ. of Illinois Exp. Sta., January, 1950.

[2] "Use of High Strength Structural Bolts in Steel Railway Bridges," Report of Sub-committee (A. G. Rankin, chairman) to Committee XV, Iron and Steel Structures, American Railway Engineering Association; *Proceedings A.R.E.A.*, Vol. 51, 1950, pages 506–540.

(To be continued)

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

BALATA BELTING

No. 2066 : 1953. Price 2s. 6d. This standard specifies requirements for balata belting used for power transmission purposes and other load-bearing applications, such as straps and slings. It also specifies details of the fabric, impregnation, balata content, quality of balata, &c., and includes appendices giving details of methods for testing, working conditions, and information to be given with the inquiry or order.

TESTS FOR CHEMICAL STONEWARE

No. 784 : 1953. Price 3s. Fifteen years after the first publication of B.S. 784, "Testing of Chemical Stoneware," a revision has now been published by the British Standards Institution. Certain of the tests specified have been found to be of academic interest only and others have been superseded by newer tests. The new document gives a number of test methods with full details of apparatus, test piece and procedure.

Woodhead New Tunnel

By P. A. SCOTT* and J. I. CAMPBELL†

A paper entitled "Woodhead New Tunnel: Construction of a Three-Mile Main Double-Line Railway Tunnel" was presented for discussion at the Institution of Civil Engineers on Tuesday, March 16th. An abstract from the paper is reproduced herewith, describing some of the difficulties encountered in driving and lining the tunnel, and the novel methods adopted to overcome them.

Of the many problems which present themselves to the railway civil engineer, the most insistent is probably that of the obsolescence of structures; the existing twin single-line tunnels at Woodhead are notable examples. These tunnels are situated on the section of the former Great Central Railway connecting Manchester and Sheffield. Both of them are now more than 100 years old and generally speaking have given good service. Inevitably, however, deterioration has taken place, making itself increasingly evident during the past twenty years, principally in the disappearance of the mortar in the joints of the stone lining. With an intensity of traffic of more than eighty trains per day in each direction, maintenance work on the tunnel lining was difficult and could not be undertaken to a sufficient extent to keep pace with the rapidly worsening situation. Taking all circumstances into consideration, the engineers recommended to the management of the London and North Eastern Railway that a double-line tunnel should be constructed. This recommendation was accepted and Parliamentary authority for the scheme was contained in the London and North Eastern Act of 1947.

The new Woodhead tunnel (3 miles 66 yards) is the third longest railway tunnel in the country. During the whole of the driving period, no resultant damage was sustained by the existing tunnels. Generally, there was not less than 77ft of rock between the new work and the old, but at the Woodhead end, because of the curve, this distance was gradually reduced, over a length of 600ft to the minimum of 27ft at the portal. The rock driven through on the curve was hard sandstone, and special care was taken in blasting in this region. It cannot be said whether or not the ruling distance could have been safely reduced.

Taking into consideration the condition of the existing single-line tunnels, it was decided that the new double-line tunnel must be concrete-lined throughout, and experience very soon proved that this was a correct decision. A thickness of 21in was adopted for the lining; this was checked by assuming that the arch had to be capable of supporting a completely shattered wedge of rock, formed by planes inclined at 30 deg. to the vertical and touching the excavation line at the shoulders. Such a wedge would be 15ft high above the crown of the excavation, and with rock weighing 160 lb per cubic foot, an arch 21in thick retains the thrust line within the middle third. (See Fig. 1.) Various assumptions about the mode of failure of the arch under excess rock loading are possible, but they all indicate that a 21in-thick arch of mass concrete has a high factor of safety for any likely combination of circumstances.

Although the shale was known to be weak, there was no evidence that it swelled or heaved, and no concrete floor was designed. The side-wall footings, however, were made massive and deep to cope with possible horizontal thrusts.

In view of the concurrent electrification of this section of line, and the fact that the new tunnel was of much greater cross-sectional area than the existing tunnels, shaft ventilation was of little importance and constructional needs were made the criteria for deciding the number of shafts to be provided. On this basis, the engineer's scheme provided for three shafts, but the alternative proposals submitted by the contractors allowed for only one construction shaft. The proposals were accepted, but it was decided to provide ventilation near the gradient peak, by driving a 45 deg. slope, 8ft in diameter, to connect with the existing No. 5 shaft.

The centre of the 16ft diameter working shaft was sited 25ft 6in to the south of the centre line of the tunnel to keep the hoisting arrangements clear of the tunnel operations, and also to provide a ventilation shaft clear of the running lines to avoid the danger to trains of any objects being dropped down the shaft. From a constructional point of view this offsetting of the shaft proved advantageous.

Type of Contract.—A contract document was prepared on the orthodox lines of a priced bills of quantities contract containing 363 items with the usual rise and fall adjustment clause to meet variations in the prices of labour and materials.

Invitations to tender were issued to seven firms of civil engineering contractors experienced in tunnelling; of these, two declined to tender, three returned priced tenders as invited, and two submitted the bills of quantities priced and totalled as a target. In examining the tenders it seemed apparent that, taking into account the known qualities of the rock to be excavated, and consequent unpredictable risks, and the ruling uncertainties as to labour and materials, contracting firms were unwilling to accept the possible heavy risks unless fully protected by quoting high rates.

In the circumstances it was decided to re-invite tenders on the basis of a target sum represented

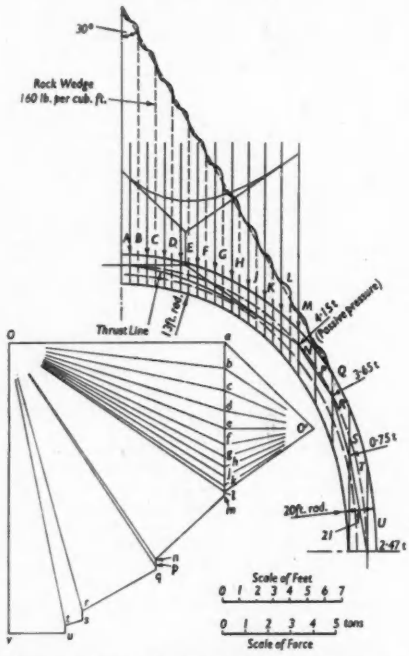

Fig. 1—Thrust Line and Funicular Polygon for Arch Analysis

by the total of the priced bills of quantities, and the payment of a fixed fee adjusted by bonus or limited penalty dependent on the actual cost and period of completion—the latter being specified as forty-two months. Furthermore, it was specified that the work would be financed through an imprest account maintained in the name of the Railway Executive, from which the contractor would be authorised by the engineers to draw cheques in his own name to recoup his actual outgoings.

The difficulties met during the execution of the work fully justified the departure from the orthodox type of contract, and a most carefully worded contract-deed was drawn up in amplification of the contract document to ensure that the contractor should have every incentive for economical working and early completion of the work. Nevertheless, the authors are of the opinion that the perfect system has yet to be devised. In this type of contract, the resident engineer has to give his approval for every purchase made by the contractor, for his methods of operation, and the salaries paid, and the bonuses offered; yet the contractor is responsible for the successful and economical execution of the work. The engineer must, therefore, exercise his powers with the utmost discretion, since refusal to approve the contractor's action and insistence on any variation could, rightly or wrongly, be blamed for lack of progress, or inefficient or uneconomical working. If a contract of this nature should go against the contractor, and he should incur the maximum financial penalty at an early stage, no really effective sanction remains and, since the subsequent cost has no direct effect whatever upon him, the contractor cannot possibly view the expenditure in the same way as the engineer and the employer. It is true that the prolongation of the contract at such a stage involves the contractor in unremunerative head office expenditure, and in the loss of his key staff from other, possibly more rewarding, work, but this may in itself produce a tendency to further expenditure by over-generous staffing and a prodigal use of materials designed to reduce the period of such losses. The position is equally unsatisfactory to the engineer, who likewise has to maintain site staff and who, while remaining responsible to his employer for the early completion of the work, is unable to influence it by any means other than those of persuasion or suggestion. As is the case in most civil engineering works where man is wrestling with Nature, the answer lies in mutual understanding between employer, engineer and contractor. So long as the work is subject to unknown or unpredictable factors, no legal documents, however carefully phrased, can be devised to meet all the contingencies likely to arise, and accordingly the operation of the contract has to be adjusted to meet circumstances as they develop.

Construction.—The contractor planned to drive a pilot tunnel 12ft wide and 12ft high from each portal, and from a central shaft, and thereafter to enlarge the pilot to full section, working only from the two portals. The proposal was that the pilot should be enlarged by radial drilling instead of face drilling. Thus the drilling gangs would work continuously and without interruption from mucking operations, receding from portal to shaft and using the shaft as their source of supplies. Giving the drillers a sufficient lead, the following gangs would charge the holes and blow a length of enlargement which the mucking gang would then remove by way of the portal. Under this system no one operation would interfere with another, since drilling, charging and blasting and mucking would be practically continuous and the gangs would have unimpeded use of the enlarged tunnel for the removal of the spoil. The system appeared ideal and the targets of 80ft per week per face for the pilot tunnel, using orthodox face drilling, and 120ft per week for enlarging by radial drilling seemed modest enough and would have ensured completion within the specified forty-two months. Unfortunately, however, in this particular class of rock, radial drilling proved to be completely impracticable and the entire system had to be abandoned. Holes charged radially blew a ragged and uncontrollable section and no method could be devised which produced the approximate profile required without undue overbreak on the one hand, or excessive trimming on the other. Undoubtedly the nature of the shaly rock contributed largely to this disappointing result, but it is doubtful if radial drilling could ever achieve entirely satisfactory results. The classical method of face drilling allows the holes to be disposed so as to remove a central wedge of rock, ease out the bulk of the rock, and finally roughly cut the shape required round the perimeter of the profile. This produces, in good rock, a well-shaped perimeter and a roughly shaped leading face in which the next round is drilled. No such refinements can be expected of the radial system, which subjects the perimeter of the tunnel to the same treatment as face drilling subjects the leading face of a tunnel. In good rock, radial drilling might be expected to cut a well-shaped face but, at best a doubtful profile. In bad rock it can serve no useful purpose. Such are the conclusions resulting from practice, but these results were not foreseen and the advantages of the successful application of the system would have been so great that it is not considered that apologies are required for the experiment. It would be of great interest to see the results of radial drilling in a close-grained rock, where the disadvantages of a roughly cut profile (and consequent overbreak) might well

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† Chief Civil Engineer, Eastern Region, British Railways.

be outweighed by the resulting economy in time and manpower.

The abandonment of radial drilling created a serious problem of reorganisation, since, as that system required only one working shaft, only four working faces were now available for the operation of face drilling.

The possible rate of progress at an enlargement face could not be predicted with any degree of certainty and experience was obtained very slowly. Because of awkward rock conditions at the portals, it was not practicable to start the driving of full-section faces directly from the outside. Instead, break-ups from the pilot tunnel had to be made a little way inside at each end, to form a chamber from which enlargement faces could be worked inwards, while the enlargement back from the break-up position to the portal was excavated very cautiously. This operation of forming break-up chambers wherever required in the pilot tunnel turned out to be a slow and difficult task, and greatly delayed the start of all enlargement faces in poor rock.

When the enlargement faces near the portals were eventually got under way, the indications were that in the doubtful shale rock forming roughly three-quarters of the length to be driven through, speeds of 20ft to 30ft per week were all that could be expected with the methods adopted at the outset. Working from the four points with straightforward access, this was less than half the speed needed to finish the enlargement in the specified time, and even then, with pairs of faces junctioning half way between the shaft and each portal, concrete lining, which could advance from the portals only, would be held up at the quarter points until the completion of enlargement work. Obviously, the opening up of enlargement faces at additional places was essential, and plans were therefore made to form and work from chambers broken out from the pilot tunnel at points ahead of the main enlargement faces.

Access to these additional chambers, however, was far from straightforward. First, all traffic and services to them passed through the main face, with consequent interruptions. Secondly, since much of the pilot (before the final abandonment of radial drilling) had been driven centrally, the pilot invert was generally 6ft above the invert of the enlarged tunnel, and before traffic could pass through the main enlargement to the extra face this floor had to be lowered.

The invert lowering was in fact carried out, although where the ground was bad it was a troublesome operation and left stretches of the pilot tunnel in an unstable condition. Work at the inner break-ups, however, turned out to be extremely difficult. Had it been possible to work to a rigid cycle of operations at the inner and outer faces, so that the traffic and services interruptions could have been phased, reasonable progress might have been achieved. With both gangs struggling in difficult ground conditions, without any regular cycle of operations, and with the risk of the inner gang being cut off by a heavy fall at the outer face, the impracticability of the arrangement soon became apparent.

It is interesting to speculate how the main problem of widening the tunnel at a satisfactory rate could have been tackled had not a disastrous roof fall occurred at this stage. The driving of the pilot tunnel had proceeded at the programmed rate of about 80ft per week and no untoward incident had occurred. The section was a small one and it had been found, in general, that the sections in sandstone stood without support, whereas in the shale sections steel ribs were required. The number of places requiring support was much greater than anticipated and it was found necessary to space these ribs much more closely than expected. Nevertheless, the driving of the pilot had proceeded fairly uneventfully and, because of the delay in completing the sinking of the shaft, was being followed at an earlier stage than originally planned by the enlargement, when the need for immediate robust support for the 31ft roof-span in shale was demonstrated in a dramatic way. In June, 1951, with a few hours' warning, a 72ft length of enlarged tunnel near the Woodhead end collapsed, causing a complete blockage which took six months to work through. Signs of a similar event impending near the Dunford Bridge end were observed about the same time; in each case the load seemed to develop about three weeks after excavation. In the second case there was time to erect additional supports and this action did prevent further movement. It was, however, a difficult and dangerous job, and a fatal accident occurred during the work.

After the work of enlarging from the Woodhead end had been brought to a stop by the fall, it became evident that it would be several months before this face could be opened up again, or access obtained through it to the inner break-up which had recently been started. After much consideration it was finally decided to drive a haulage-way clear of the tunnel section round the obstruction to allow work to be resumed beyond the collapse. This was successfully done, and the experience gained encouraged the idea that such haulage-ways or by-pass tunnels, might be used wherever uninterrupted access was needed to points in the pilot tunnel beyond enlargement faces. Accordingly, the original by-pass round the fall was extended, in the form of a tunnel parallel to the pilot and 50ft south of it, and connections across to the pilot were formed wherever required. At Dunford Bridge, another such by-pass tunnel was started 600ft inside the portal, and access to inner break-ups was obtained through it. In the end, a maximum of nine enlargement faces were worked at one time, using a system involving about 9500ft of by-pass tunnel, and the original expedient to deal with the fall disaster had become the solution to the access problem.

The planning of the scheme of by-passes and break-ups was quite a complex operation, depending on estimates of relative progress in by-pass tunnel and in enlargement face, in different types of rock, and on traffic capacities of the single-track by-pass tunnels. The need to ensure uninterrupted progress of concrete lining, working inwards from the portals, also affected the programme of work. In order to plan operations, to follow the varying fortunes of the headings day by day, and constantly to revise the tactics without losing sight of the main objectives, a diagram was evolved on which the past, present and future progress of all headings could be plotted. This diagram is reproduced in Fig. 2, and a study of it will reveal the rates of progress of the various faces and the way in which the available face gangs were deployed in the efforts to keep ahead of the potential progress of the concrete lining.

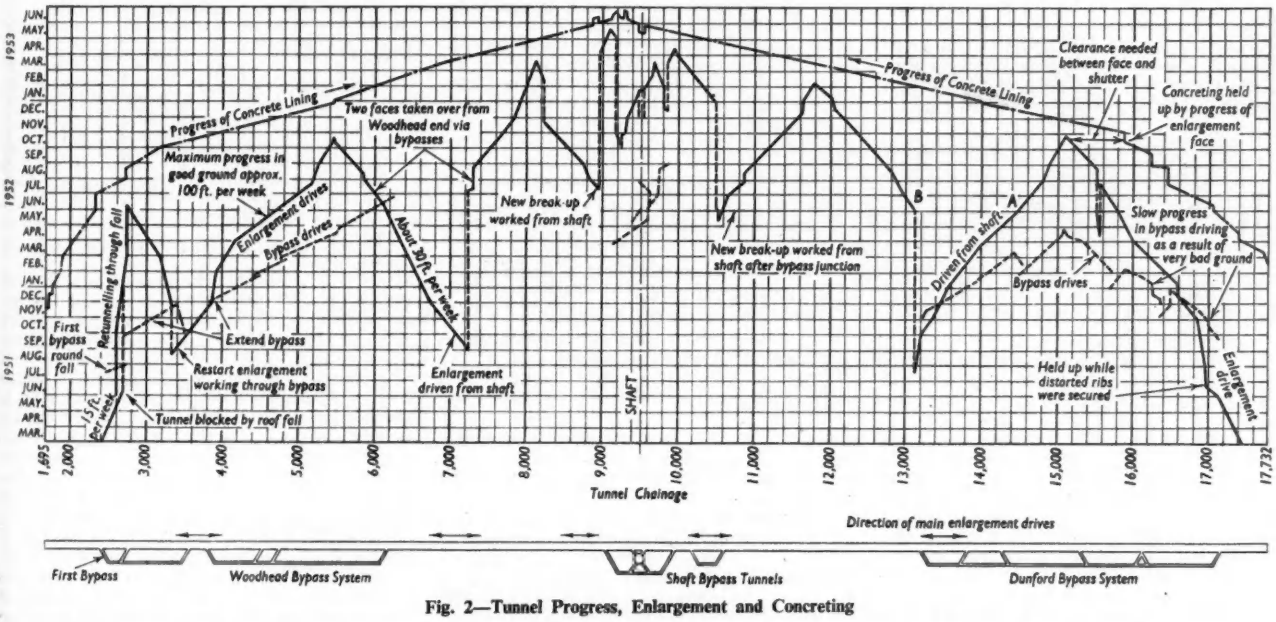


Fig. 2—Tunnel Progress, Enlargement and Concreting

Many difficulties were met; progress in driving the by-passes did not come up to expectations and rock falls were encountered even in such small adits, and traffic arrangements for the removal of spoil and supply of stores and tools to the face sometimes broke down, but the main problem had been solved and progress was ensured. The system is one which deserves serious consideration in any tunnelling work involving the driving of a long tunnel without intermediate access by shaft or adit. For example, during full-face driving from the two portals of the tunnel, a parallel connecting by-pass tunnel could be driven from each portal, thus enabling full-face tunnelling to be carried on at several pairs of faces simultaneously, by turning off at predetermined points from the by-passes to the line of the tunnel. The by-pass tunnels would, in fact, be adits, but the adits would be parallel to, instead of (as is more usual) at right angles to, the line of tunnel. Where no pilot tunnel had previously been driven, ventilation of the inner faces would present a problem, but not an insoluble one.

Concreting.—The shuttering system was designed to permit the concreting of the whole of the side walls and arch, in long lengths, in one operation. Consequently a large and heavy shutter was built, capable of supporting about 6ft thickness of wet concrete over its span of 27ft, and at the same time being readily movable, easily struck and reset, and clear of traffic on

two 2ft gauge tracks in the tunnel centre. The 100ft shutter weighed 230 tons, so that the rails it ran upon had to be firmly set. It was necessary to have the carriage correct for line and level, and it followed that the position of the rails determined the setting of the whole lining. The excavation of the footings, the setting of shutter rails, and the concreting of the footing and haunch of the lining had all to be carried out between the excavation to full size and the concreting of the main lining, but these jobs could all be speeded up more or less without limit. It was the placing of the side walls and arch concrete which set the pace, and the lining organisation centred round this process.

Had the concrete surfaces during the placing in the side walls and arch been kept approximately horizontal, even the maximum pump output would have been insufficient to maintain an adequate rate of rise, especially at shoulder level, where overbreak was nearly always very large. A sloping flow method was therefore adopted in which concrete was built up as quickly as possible to crown level at the back of the shutter, against the stunt end of the last length completed, and thereafter all pumps were connected to valves in the crown, with the concrete flowing forwards and downwards to complete the side walls up to the forward stunt end. The pumps were connected to valves as far back as possible and the pipes were moved forward only when the resistance to further concrete being forced in became excessive. Concrete was thus squeezed between the packings and ribs under the pump pressures, and such pressures were at times sufficient to buckle the shutter ribs and skin plates in the crown and shoulders.

Clearly the success of this system depends upon a high level of supervision and inspection, and on the conscientiousness and skill of a large number of operators. The uniformity and consistency of the mix, and the scheme of control and testing applied are also of great importance, and these will be the subject of a separate paper. At best, it was possible to concrete three lengths (of 80ft or 100ft) on alternate weeks, and two lengths intermediately.

Striking, moving and resetting times were kept low (and sometimes under the twelve hours allowed for) except where water had to be diverted extensively after the shutter was moved forward, or where rib distortions necessitated cutting back steel and rock at the last moment, but the actual concreting times, as represented by the twenty-four-hour average concreting period, seldom represented maximum pump output. The factor limiting the average rate of pumping was the rate of feeding the mixers with dry batches, and this in its turn was dependent upon the speed of shunting bogies and hoisting hoppers. The skill needed to handle these operations continuously for twenty-four hours at maximum speed was usually beyond the powers of the labour available.

As an overall measure of the final rate of progress, it may be recorded that for the last seven months of lining operations the average cycle was 2·12 moves of each shutter per week, representing totals of 392 linear feet per week or 3590 cubic yards per week.

The consulting engineers for the Woodhead new tunnel were Sir William Halcrow and Partners, and the contractor was Balfour Beatty and Co., Ltd.

Electro-Thermal De-Icing Equipment

In the surface heating equipment described, resin layers sandwiching a metal resistance element are each sprayed directly on to a surface requiring icing protection, forming a mat. When used for de-icing, rather than for anti-icing, the mat is divided into isolated regions which are cyclically heated. Its original applications were associated with air-intake installations but D. Napier and Son, Ltd., Luton, has now prepared production facilities for complete aircraft de-icing systems and for other commercial and military applications.

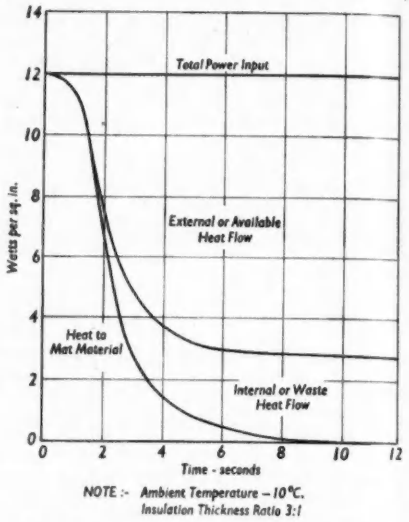
THE accumulation of surface ice on an aircraft is a familiar hazard in aviation, but as with many other problems of aircraft operation, it is one which the advent of the gas turbine and higher air speeds have made more serious. Not only are high speed aircraft more susceptible to ice accretion due both to their laminar flow aerofoils and their higher forward speeds, but the greater air consumption, particularly of the turbo-jet, render them also particularly intolerant to ice formation at air intakes. It was in the prevention of ice formation at air intakes, whether of primary or secondary function, that conventional protection equipment proved least adequate and as a consequence we recently saw demonstrated, at the Luton works of D. Napier and Son, Ltd., an electro-thermal surface heater which has now been sufficiently developed for general application. Its use had hitherto been largely confined to engine installations on military aircraft and had not been disclosed. With this system a mat is sprayed on to the surface consisting of two films of "Araldite" resin between which is sprayed a resistance element either of commercially pure aluminium or of copper alloy.

It might usefully be pointed out that early protection systems had depended on mechanical or chemical means. One of the former techniques employed a rubber mask over, say, the leading edge, which was pneumatically inflated cyclically, the ice layer being first broken and then dislodged by aerodynamic forces.

In the adoption of thermal methods of protection there are two principles of operation available. One termed "anti-icing," is to prevent any ice forming at all and this can be further subdivided into wet anti-icing and dry anti-icing. In the wet anti-icing method, the water caught is kept just liquid and will run back and tend to freeze aft of the protected area; it is thus limited in application. With dry anti-icing all the water caught is completely evaporated.

In the second principle, termed "de-icing," ice is allowed to form and is shed periodically before it can reach sufficient proportions to have a serious effect, the treated area being divided into isolated zones which are cyclically heated. A very great thermal economy is thereby achieved since the heating is intermittent, the actual saving being dependent on the ratio of "heat on" and "heat off" time, both of which can be varied to suit any particular application. A typical ratio is 1 : 10, and because sufficient heat is applied only to melt the interface between the ice and the aircraft surface, the total power requirements can be as low as one-twentieth of those required for anti-icing. This method can be adapted to any areas where the shedding of ice will not have a secondary detrimental effect, such as the main flying surfaces of the aircraft, the propellers and in the case of helicopters, the rotor blades.

When considering the heat source for thermal anti-icing or de-icing systems there is stated to be a number of advantages for an electrical system. Perfect control and distribution of energy is possible with the ability to grade the heat to suit the requirements of any particular surface. As there is not the complicated ducting or double skinning associated with hot air or gas systems, the installation is basically simple,



NOTE :- Ambient Temperature – 10°C. Insulation Thickness Ratio 3:1

Fig. 2—Typical Heater Mat Efficiency Curve

and can be installed on existing aircraft with few, if any, structural alterations. It is particularly suitable for propeller protection and for small auxiliary intakes where protection by any other means would be practically impossible. The thermal efficiency also of an electric heater mat is high, since it can be applied directly to the outside of the surface to be protected, and is therefore in direct contact with the ice deposit. The very small thermal lag obtained is another advantage in cyclic de-icing heating. This small thermal lag, which is of the order of five seconds, is extremely important in de-icing by permitting rapid heating and cooling to obtain clean ice-shedding. In this way water is prevented from draining aft of the mat and subsequently refreezing. As electrical heaters are normally applied to the outside of the structure and are thermally insulated from it, there is no risk of thermal stress problems arising.

The advantages of fabricating the heater by a spraying process directly on to the surface to be protected particularly when compound curvatures are considered, have been exploited in the Napier construction. With the normal

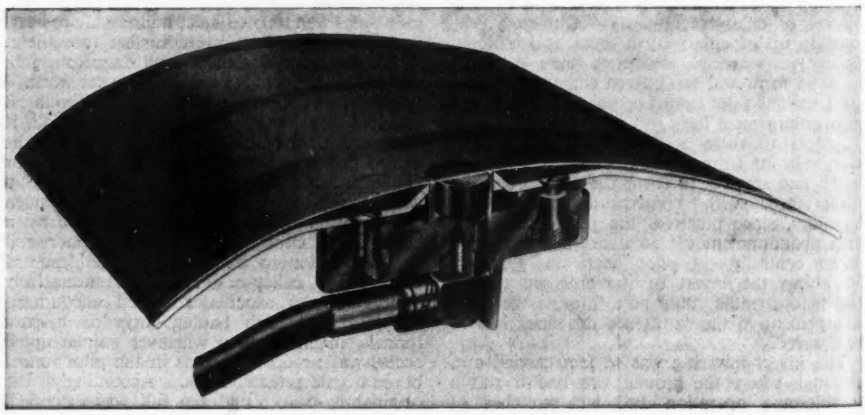


Fig. 1—Heater Mat in Part Section

tolerances possible in sheet metal work it is difficult to apply a prefabricated mat without entrapping air at the attachment face. This trapped air is liable to cause blistering and overheating when heat is generated by the elements, but a sprayed application of the base insulation ensures intimate contact with the surface. Similar considerations also show that the electrical element itself is advantageously applied by a spraying technique, which also satisfies the requirements by permitting adjustment of the resistance to any specified power loading during the design stage.

The base insulation of the Napier mat consists of a layer of "Araldite" thermo-setting resin applied by a flame spray gun. The electrical conductor is also applied by a flame spray gun to the resistance and pattern called for by the particular heat distribution required, and is provided with suitable terminals for connection into the electrical system. The outer "Araldite" insulation layer is sprayed on and finally finished as a highly polished surface. The heater mat may be coloured to conform with the customers' specification without affecting the characteristics of the mat in any way.

The mat may be applied to the surface of suitable shapes by mechanical means, which normally take the form of gun traversing gear linked by a suitable mechanism to the workpiece turntable in such a way that the rate of pass of the gun across the workpiece can be controlled. The heater element is sprayed in a similar way, the rate of wire feed, the rate of pass and the number of passes being selected from experimentally determined curves to give the required resistance. Close control is kept over all spraying conditions to ensure that the overall resistance and degree of uniformity are obtained. In general, objects of single uniform curvature, of aerofoil section, and of spinner section can be treated by mechanical methods, providing the quantity required warrants the cost of mechanisation.

For more complex shapes, a combination of hand and mechanical methods is normally employed. In both cases the process may be broken down into six main operations: terminal fitting, base coat application, element application, top coat application, testing and the final finish. A range of standard terminals is available designed to suit the S.B.A.C. system of wiring and to fulfil the requirements of the R.A.E. Tech. Memo Number DES.1.

The total thickness of the Napier mat is 0·040in to 0·050in, depending on the conductor thickness, and its corresponding specific weight is 0·27 lb to 0·32 lb per square foot, allowing one miniaturised terminal per square foot. A high thermal efficiency is achieved although the electrical insulation is also a good heat insulator. Fig. 2 shows a typical heat distribution of a mat dissipating 12W per square inch. The mat is constructed to a specification approved by the Ministry of Supply and has successfully undergone a M.O.S. approved type test consisting of the climatic tests of D.T.D. 1085B, and the vibration, electrical insulation and inflammability tests of British Standard G.100 for class 1 airborne equipment. Other tests include powered endurance tests in which 1000 hours of cycled operation at 10W per square inch with water cooling and 1000 hours' continuous and 1000 hours' cycled operation at a surface temperature of +70 deg. Cent. have been successfully achieved. With cold air wind tunnel cooling, power loadings of 40W per square inch have also been maintained without failure. The heater has proved to be unaffected by all aircraft fuels, oils and hydraulic fluids, and flexural fatigue tests have been carried out with mats mounted on resonant bars. During these tests, at the severe condition of a strain at the surface of the mat of ±0·176 per cent at which the surface stress in the bar was ±15,000 lb per square inch, the element failed at 4·1 million cycles, while 48 million cycles were achieved without failure at a surface strain of ±0·153 per cent. Type tests, consisting of full power tests, tests at +70 deg. Cent. and electrical insulation tests, are also carried out on at least one sample of any specific installation.

The maximum operating temperature for the Napier mat is at present fixed at 100 deg. Cent., and whereas this is more than adequate for use in icing conditions where cooling is severe, overheat protection is needed to safeguard the heater in cases of less severe cooling, for example, on emergence from icing conditions into dry air, or when ground testing. A thermal cut-out unit utilising a resistance sensing element has been developed for this purpose.

The resistance of the mat to sand abrasion has been proved by tests on aircraft, including considerable service in tropical conditions, while the rain erosion properties of the standard insulation have also been established by flight tests in rain by a "Venom" aircraft. For high-speed applications, use is made of a final outer layer of a modified resin (pigmented if required), which accelerated tests have shown to have superior erosion properties.

For yet higher speeds the application of a metal protective layer is adopted and Napier's have brought into service a whirling-arm rig to assist in its further development.

Production and Maintenance.—A visual examination is all that is normally required at minor inspection periods. At major inspections, however, a more extensive visual check would be made and any region showing evidence of mechanical damage investigated further by insulation and resistance checks employing normal servicing equipment.

Schemes have been evolved whereby local repairs may be carried out in the workshops without any difficulty using the hand spraying methods. The damaged section may be removed if necessary, right down to the base metal, and the base insulation replaced by building up with synthetic resin. A new section of heater element is then grafted in by spraying, checked for uniformity, and the top insulation applied.

The workshop equipment includes spray guns of standard design and production facilities include both manual and mechanical spraying apparatus, as these operations have special applications to both component contour and repair schemes. A number of specially developed multi-purpose spraying machines are also installed.

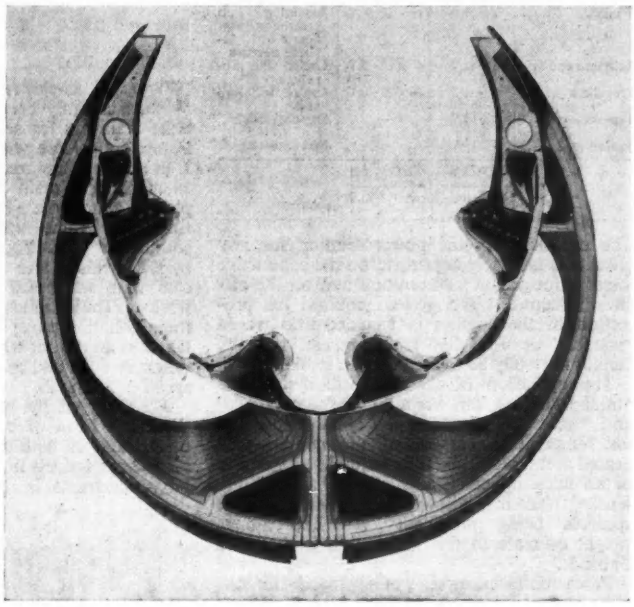


Fig. 5—Intake for Turbo-Propeller Engine

Cyclic De-Icing Applications.—In a typical all-electric protective system for a transport aircraft the areas particularly suited to the application of the mat are the main plane, tailplane and fin for de-icing and the engine intake and propeller spinner for anti-icing. The propellers would be electrically de-iced and the windscreen anti-iced. Table I shows the various loads required for this case, these being divided into continuous and cyclic loads. From a consideration of the design meteorological conditions, aircraft geometry and a selected safe allowable thickness of ice accretion, a cyclic ratio of "heat on" to "heat off" time of 1 : 10 is most suitable for the cycled areas of the main planes, tail units and propellers. The main planes are thus conveniently divided into twenty areas with a continuously heated parting strip along the leading edge (where ice could

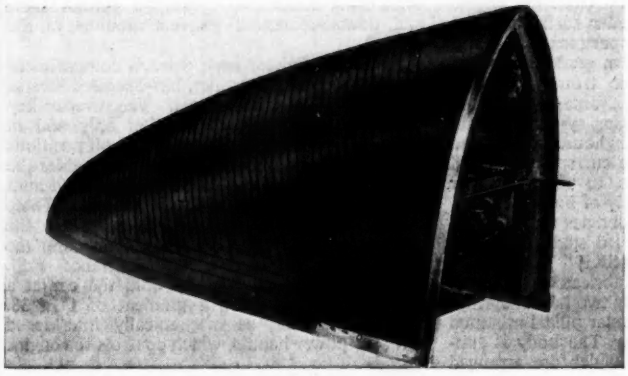


Fig. 3—A Typical Wing Section

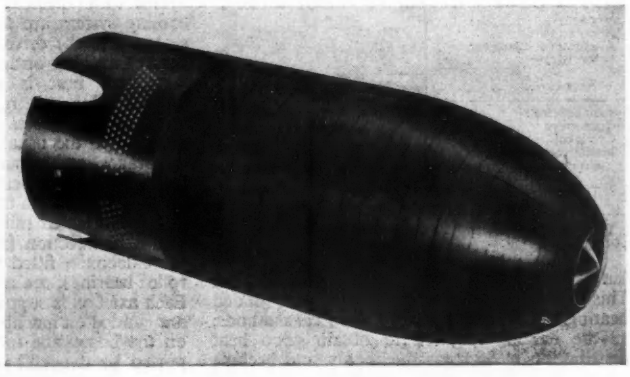


Fig. 4—Nose Fairing in Turbo-Jet Engine

not be dislodged aerodynamically), and chordwise continuously heated dividing strips to ensure clean shedding of each cycled area. The heat requirement for these continuously heated zones is that for wet anti-icing, i.e. just sufficient to prevent bridging of the gaps by ice, and the requirement for the cycled areas is that sufficient to break adhesion and shed quickly and cleanly to prevent runback.

TABLE I—*Summary of Loads for Electro-Thermal Protection for a Typical Four Engined Turbo-Prop Transport*

Weight—120,000 lb. Span—130ft.
Cruising speed—350 m.p.h. at 20,000ft.

Component	Power input		Remarks
	Continuous	Cyclic	
Wings	26·5kW	10 × 32·8kW	Assuming no protection inboard of inboard nacelles
Tailplane and fin	18·5kW	6 × 15·8kW	Cycled with propellers
Propellers	—	4 × 12·0kW	Cycled with tail unit
4 engine intakes ...	28·0kW	—	Dry anti-icing
4 spinners	12·0kW	—	Wet anti-icing
	85·0kW	48·6kW max	
	Max. total input 133·6kW		

The optimum specific power loading for any given case is largely dependent on the conductive losses through the ice accretion and on the aircraft structure. The power required for protection of the engines is included and would probably be for dry anti-icing, as runback cannot normally be tolerated in an intake.

The operation of the complete system for initial switching on, variations of "heat on" and "heat off" times of the cyclic areas, and for temperature control of the continuously heated areas, would be fully automatic by means of an icing indicator and suitable temperature sensing elements, pilot warning and over-ride controls being provided. An approximate weight estimate of this installation is shown in Table II.

Production examples of sprayed aircraft components are shown in Figs. 3 to 5. Fig. 5 illustrates the engine and oil cooler intake for

TABLE II—*Weight Summary of a Typical Four Engined Turbo-Prop Transport, Electro-Thermal System*

Aircraft all-up weight—120,000 lb. Span—130ft.

Component	Unit weights	Remarks
	lb	
Propellers and spinners :		
Heaters	23	
Slip rings	40	4 × 4 blades
Wiring	13	
Total	76	
Wings :		
Heaters	46	3 phase wiring to each area
Wiring	352	
Total	398	
Empennage :		
Heaters	16	3 phase wiring to each area
Wiring	45	
Total	61	
Engine intakes :		
Heaters	5	3 phase wiring to each area
Wiring	13	
Total	18	
Power supply :		
Alternators	220	
Alternator control gear ..	86	
Power wiring	73	
Total	379	
System control :		
Contactors	97	Main and cyclic
Cyclic control gear	25	
Miscellaneous switches, instruments	10	
Total	132	

Total weight of system, 1064 lb. 0·89 per cent of aircraft all-up weight.

the "Double Mamba" turbo-prop engine. This is a dry anti-icing application with graded heating and is most suited to electrical methods, as the ducting required to obtain good heat distribution by hot gas methods would become extremely complicated ; again the compound curvature makes it an ideal application for the mat. Electrical heating is also most convenient for small auxiliary air intakes, which are often situated in remote parts of an aircraft ; the power requirements are relatively small and hence can usually be catered for from existing generating capacity.

The process is used on one of the four alternator cooling air intakes on the D.H. "Comet."

By early consideration of the electrical system as a whole, in conjunction with the requirements of the icing protection system, load sharing arrangements can be devised making weight saving possible. The company suggests that the undercarriage could be operated electrically or in certain cases the alternator might well be used as an engine starter motor. In cases of long endurance in icing conditions, electrical protection shows an advantage even when the whole of the weight of the generating equipment is debited against it, for fuel consumption figures make the curve of total weight against endurance in ice rise quite steeply for a hot gas system, whereas the curve for an electrical installation is considerably flatter.

Diesel-Electric Railcars for South America

TWO diesel-electric metre gauge railcars have recently been supplied to the Bolivian State Railways for service on the lines between Potosi and Sucre where the ruling gradient is 1 in 33 and the track rises to an altitude of 14,000ft. The main contract for these cars was placed with the British Thomson-Houston Company, Ltd., which supplied the power equipment. The bodies and bogies were built by D. Wickham and Co., Ltd., of Ware, and the cars were assembled and tested in this firm's works. These railcars, one of which is illustrated on this page, have an overall length of 60ft and an overall width of 10ft 5in. They each weigh 30 tons and are designed for a maximum speed of 70 m.p.h.

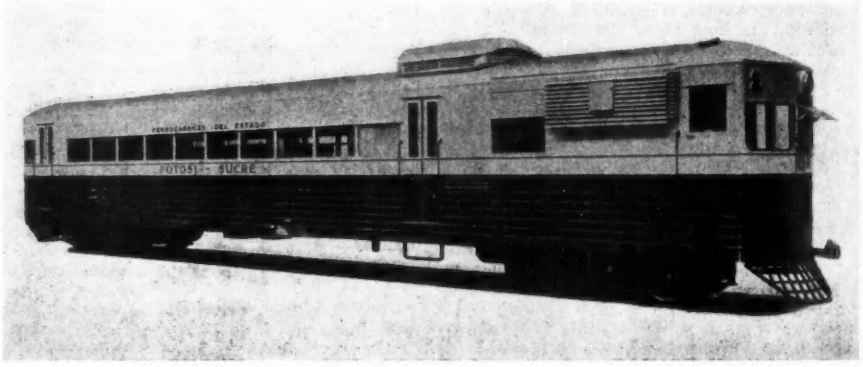
The body of the railcar, following the usual Wickham form of construction, is of stressed design and is built up of solid drawn square steel tubes welded in the form of a box girder. No underframe is required and the body is mounted on springs attached to the bogies. Each side of the tubular steel body frame is panelled with aluminium sheet and the intervening space is filled with insulating material. Accommodation is provided for forty-four first-class passengers in each car, and an enclosed driver's compartment is situated at each end.

Hot water heaters supplied from the engine cooling system are fitted under each passenger seat and in the driver's compartment. When a car is travelling on long down grades, however, very little heat is available from the idling engine. For this reason advantage has been taken of the rheostatic braking system fitted in addition to the usual Westinghouse compressed air brakes, and some of the current is diverted from the brake resistances to electric water heaters to maintain the supply of hot water.

The fabricated mild steel bogies are built up into a box section from rolled steel plates and the axleboxes, fitted with "SKF" self-aligning roller bearings, are also of fabricated mild steel. Each axlebox is supported by two helical springs and guided on machined tubular pillars mounted on the bogie side members. The body is supported by two coil springs which are arranged on an unsprung pivoting bolster located by the centre pin of the bogie.

Each wheel of each bogie is fitted with two cast iron brake blocks, the brake rigging being fully compensated and operated by Westinghouse compressed air fittings. A hand screw brake, also fitted to each bogie, is operated from the driver's compartment.

The railcars are powered by engines supplied by Davey Paxman and Co., Ltd., of Colchester, and are arranged for operation at the high altitudes encountered in service. The "V6RPHXL" engine installed is equipped with an exhaust gas pressure charger and is de-rated to give an output on site of 230 b.h.p. at 1250 r.p.m. The engine is coupled directly to the B.T.H. main generator. This 320V, 420A generator is a six-pole, single bearing machine, and its fabricated steel magnet frame carries supports on which are mounted the auxiliary generator and exciter, as can be seen in one of the photographs we reproduce on page 423. These machines, together with the Westinghouse compressor mounted at the side of the engine, are driven by belts from a pulley on the extension of the main generator shaft.

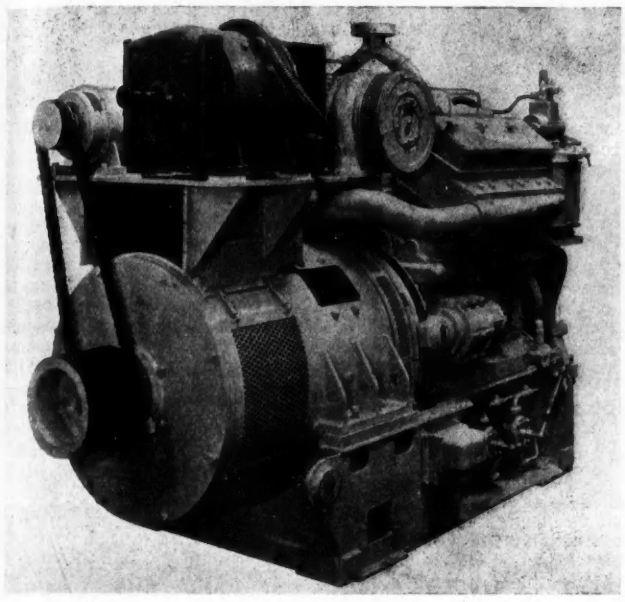


Diesel-Electric Railcar for Bolivian State Railways

One axle of each bogie is driven by a B.T.H. traction motor continuously rated at 320V, 210A, 1035 r.p.m. at an altitude of 15,000 ft. Each motor is mounted on the railcar body, the drive being transmitted through a cardan shaft and double-reduction gearbox mounted on the axle.

A control unit in each driver's compartment includes a power controller, key-operated reverse switch, and instrument panel. The reverser key is removable in the off position only and in addition to the forward, reverse and off positions it has an engine only position which enables the engine to be run up and the control tested without actually applying power to the motors. There is also a braking position which brings the rheostatic brakes into effect by connecting the traction motors across the resistance unit. This braking is arranged to hold the car at a speed of 30 m.p.h. on a gradient of 1 in 33. The reverser key is mechanically interlocked with the power handle, which controls the engine speed.

The driver's instrument panel, mounted alongside the control unit, contains a speed



Engine Generator Set for Railcar

indicator, load ammeter, air pressure gauge, warning lights and the engine starting switch.

The series wound traction motors are supplied by the main generator, which has a self and separately-excited shunt field winding together with a differential series field winding. The separate field of the generator is energised by the small exciter, which is also equipped with a small stabilising winding energised from the battery. The engine is provided with a fixed maximum fuel stop fitted to the fuel regulator to limit maximum engine torque. The main generator has an inherent characteristic which limits maximum volts at light current and the maximum stall current. When the demand made by the generator exceeds the limit of torque permitted by the engine fuel stop there is a fall in engine speed ; but by energising the main generator separate field from a source which is sensitive to speed, the reduction of generator output due to the drop in speed is considerably emphasised and balanced torque conditions are reached with only a small drop in engine output.

When the engine speed is reduced the maximum current available from the generator is progressively reduced until idling speed is reached, at which the maximum current available is sufficient for manœuvring under light load conditions. By this means continuous and smooth variation of railcar speed and tractive effort is obtained between standstill and full horsepower, simply by varying the engine speed.

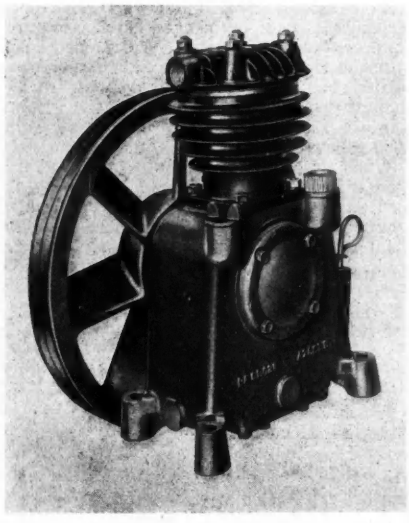
5·25 c.f.m. Compressor

A PEDESTAL-MOUNTED compressor unit, the " 200 SAS," designed to achieve a long life with the minimum maintenance, is now in quantity production by the Hymatic Engineering Company, Ltd., of Redditch, Worcs. It has a displacement of 5·25 cubic feet per minute at 750 r.p.m. and a working pressure of 100 lb to 150 lb per square inch. The unit may be incorporated as initial equipment or as an optional extra on tractors, special vehicles, machine tools and powered plant of all kinds for such duties as spray painting, spraying horticultural and insecticide solutions, pneumatic greasing, tyre inflation, the operation of pneumatic tools, braking systems, jigs and fixtures and scores of other compressed air applications. When necessary, the unit may also be operated at 1000 r.p.m. to give a displacement of 7 cubic feet per minute against a working pressure of 100 lb per square inch.

The single-stage, 200 c.c. capacity, high-duty cast iron cylinder, bore 2·67in and stroke 2·16in, is heavily finned so that in conjunction with the finned cast aluminium cylinder head and the generous inlet and outlet ports, a consistently low delivery temperature is maintained. The air passes through a filter and silencer, and enters the cylinder through a large diameter, low lift, light-weight annular valve. On the up stroke of the piston the air is compressed and passes to the delivery connection via a central annular plate valve. Unlike the air inlet valve, this is fitted with a wave type annular spring.

The light alloy piston has a scraper and two compression rings and a case-hardened steel gudgeon pin. The connecting-rod, of a forged steel, carries a phosphor-bronze bush at the small end and steel backed, white-metal-lined shell bearings at the big end.

A forged steel crankshaft is carried in large diameter ball bearings and housed in a cast aluminium crankcase. A dip rod on the big end regulates the splash lubrication of the running gear. Between the bearing and the flywheel boss is a flanged distance piece which acts as a distance collar, so clamping the inner race of the bearing, provides a hardened surface to co-operate with the lip on the seal and serves also as a convenient means for extracting the



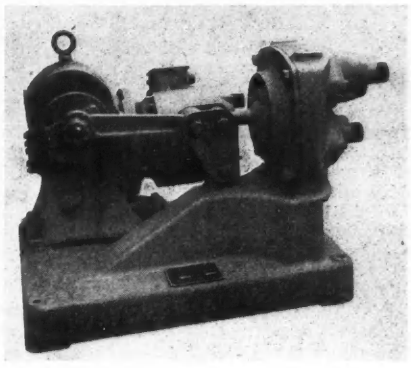
5·25 c.f.m. Compressor Unit

seal. A fan pulley grooved to accommodate twin vee belts and of adequate dimensions to ensure a large flow of cooling air over the cylinder, is keyed to the shaft and retained by a central fixing screw. The unit complete weighs 38 lb and absorbs about 1 h.p. at 750 r.p.m.

Diaphragm Pumps

FOR some years Wilkinson Rubber Linatex, Ltd., of Camberley, Surrey, has manufactured a range of centrifugal pumps for handling solids in suspension and corrosive liquids. Now, in order to provide a means for handling rates of discharge below those for which the smallest centrifugal pumps are suitable, the firm has introduced two diaphragm pumps. These pumps will handle corrosive liquids and abrasive solids in suspension at temperatures up to 65 deg. Cent. One of the pumps is driven by a small geared motor and the other is a portable hand operated unit. Both models of the pump are capable of discharging up to 8 gallons a minute against a head of 25ft, and a suction lift of 10ft when using a 1½in bore hose.

The motor-driven pump is illustrated on this page and some of its principal parts are common to those of the hand operated model. The assembly consists essentially of a rigid cast base on which is mounted a geared motor driving the pump through a connecting-rod and plate



Rubber-Lined, Motor-Driven Diaphragm Pump

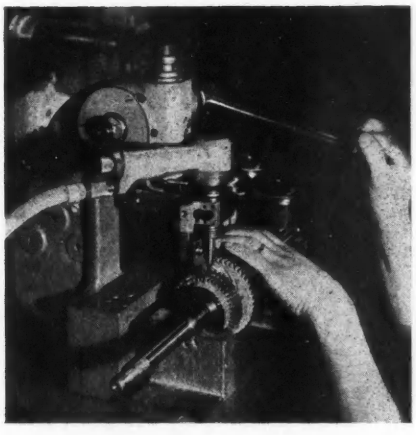
couplings pivoted on a fulcrum block. The standard geared motor gives sixty-eight strokes a minute, but in cases where lower rates of discharge are required, and for handling liquids appreciably more viscous than water, higher ratio gearing can be supplied. A simple means of stroke length adjustment is also incorporated to enable the rate of discharge to be varied to suit particular requirements.

The body of the pump is lined with rubber and the diaphragm and the non-return valves in the suction and delivery branches are also made of rubber. Corrosion resistant material is used for the suction and discharge hose connections projecting from the back of the pump body. Rubber bearings have been fitted on the connections to the fulcrum plate to obviate necessity for lubrication when the pump is operating.

Pneumatic Swaging Machine

PARTICULARS have been received of a machine which has been developed at the works of the British Vacuum Cleaner Company, Ltd., of Leatherhead, Surrey, for swaging or crimping wires on fractional horsepower motors. This machine consists of a small arbor press to which there has been fitted an Atlas pneumatic riveting hammer, and its arrangement can clearly be seen in the illustration below.

The rivet snap blank of the pneumatic hammer has been modified to take a small insert punch,



Pneumatic Swaging Machine for Commutators

and a guide foot at the side of the punch is designed to press the wires into position for the swaging operation. When the arm press is

moved down by the operator the air supply to the hammer is automatically switched on. With the wires held in position by the foot the hammer swages them in the slotted riser of the commutator supported in a fixture on the machine table.

We are informed that since the new machine was introduced the time for the swaging operation has been reduced from four to two minutes, and consistently better results have been obtained.

Boring and Milling Machine

We are informed by the Rockwell Machine Tool Company, Ltd., Welsh Harp, London, N.W.2, that it is shortly to install for demonstration purposes a new co-ordinate boring machine built by Berliner Maschinenbau-A.G. This machine, illustrated below on this page, is designed for drilling, boring and milling components to precision limits without the use of jigs or fixtures.

The spindle head moves transversely on a saddle which in turn can be traversed longitudinally along a rigid bridge carried on heavy columns behind the table. The respective transverse and longitudinal movements are 47in and 31½in and the spindle quill has a vertical movement of 12in. The work table, which can be adjusted vertically over a distance of 16in by power, can be removed to allow the machine to accommodate very large workpieces.

All the machine slides, including the table, are automatically locked hydraulically when the spindle is in the boring position. The hydraulic system provides steplessly variable feeds from 0in to 4in per minute for milling and a rapid traverse rate of 157in per minute. It is possible to set the machine to operate on an automatic cycle of quick approach, feed and rapid return.

An interesting point in the design of the machine is in the rapid way co-ordinate settings can be made by moving two groups of counter-wheels on the spindle head. These wheels control two sets of end measuring rods ; one group for the transverse and the other for the longitudinal movements. The digits of the measurements are set up on dials similar to those of a calculating machine. On machines made for the English market there are six digits in each dial group, the last digit being 0·0001in and increasing in steps of two. Thus, for example the machine could be set to 22·5266in or 22·5268in. The machine's movements can be preselected ; in other words, the last co-ordinate setting of the spindle speed and spindle feed can be made whilst the previous bore is being machined. When the spindle has been removed under power from the bore a button is pressed and this causes the next required combination of the built-in end measures to be set up. It is stated that the guaranteed accuracy of the machine is plus or minus 0·0008in and when required much closer measurements can be obtained.

As already mentioned, the machine employs two sets of end measuring rods and these rods are grouped in six magazines and are totally enclosed. The control push buttons are interlocked in such a way that it is impossible to select a wrong movement. In addition to the co-ordinate settings the milling feed, boring feed and spindle speeds can also be preselected and the depth of bore automatically limited. If required the machine can be equipped for the co-ordinate settings to be made automatically from a punched card for repeat settings when machining batches of components.

Cleaning Equipment for Coal Tar

Solid particles suspended in coal tar cause considerable difficulties in tar handling systems at gasworks, as when they settle out in the tanks and separators they blanket the heating coils and prevent the effective heating of the tar which is necessary to ensure proper separation of the liquor. We learn from the North Thames Gas Board that much of this trouble has been overcome by a new design of filter made by Russell Constructions, Ltd., 8, Adam Street, London, W.C.2, which has been adapted for filtering coke oven tar at the Beckton gasworks.

In the new filter, illustrated below, the tar to be cleaned is poured on to a stainless steel screening cloth, which is vibrated at a high frequency but very small amplitude. The filtered tar gravitates to the tar collecting system whilst the solid material is retained on the screening cloth. An endless chain of brushes moving over the cloth continuously brushes the deposited solids into a receiving vessel at one end. Experiments carried out with cloths of different meshes showed that the most suitable for this application was 120 mesh, which gave a throughput of 1000 gallons of tar an hour.

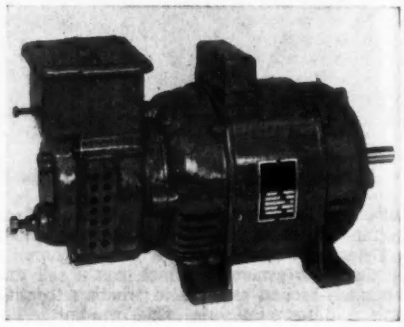
When this filter is operating it is stated that there is no sign of screen cloth blinding, and the tar feed can be interrupted for long periods, after which, providing a hot tar feed is restored, the plant restarts work satisfactorily. Intermittent feeds of hot liquor have not been found to interfere with the passage of the tar through the screen.

We are told that investigations are to be carried out with the filter to study the possibility of reducing the water content of tar. It is known that many of the problems of separating water from tar are associated with the presence of solids in suspension, and it is expected that their removal will allow easier separation of tar and water.

Four-Inch Electromagnetic Motor Brake

The range of 6in and 8in electromagnetic brakes made by Lancashire Dynamo and Crypto, Ltd., St. Stephen's House, Victoria Embankment, London, S.W.1, has now been extended by the introduction of a 4in brake designed for integral mounting on small L.D.C. motors up to about 2 h.p. at 1500 r.p.m. The new brake, which is illustrated herewith, has a maximum dynamic frictional torque of 7 lb-ft, compared with 25 lb-ft for the 6in brake and 45 lb-ft for the 8in brake.

Briefly, the brake consists of a 4in diameter steel disc keyed to the motor shaft extension,

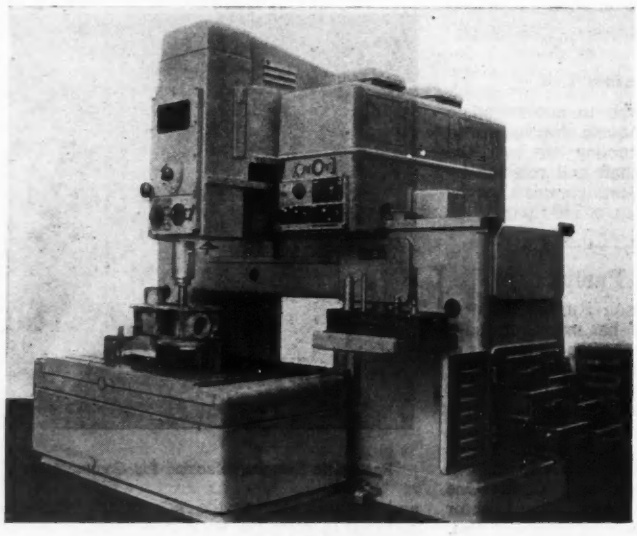


1 H.P. Drip-Proof Motor Fitted with 4in Electromagnetic Brake

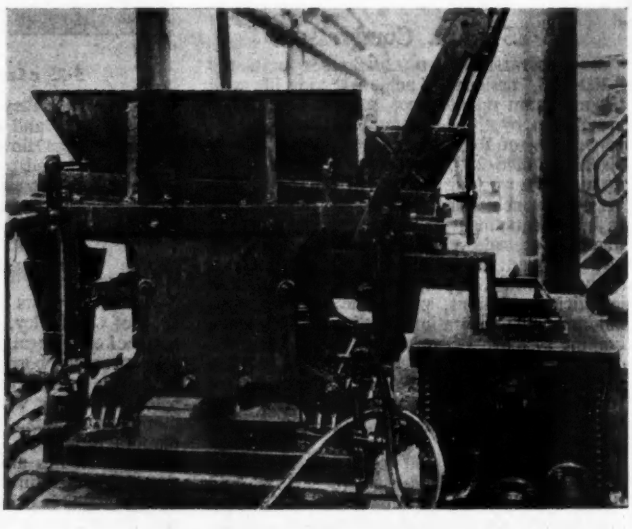
with asbestos fabric friction surfaces on each face of the disc. A pivoted brake lever arm with a coiled tension spring causes pressure to be applied on one face of the friction disc, through the medium of a suitably designed steel ring, and the other side of the friction disc comes in contact with a mating surface on the fixed backplate. When the brake solenoid is energised it pulls the arm against the coil spring tension, thus releasing the braking pressure on the friction disc. Suitable adjusting screws are provided to adjust the air gap, to operate the emergency release, and to adjust the brake pressure.

Our illustration shows the 4in brake fitted to a 1 h.p., 1420 r.p.m., drip-proof, squirrel-cage motor. It will be seen that no bedplate is required, as the brake is designed as an extension of the motor end cover so that the whole assembly is self-contained.

Whereas the 6in and 8in brakes are designed



Co-ordinate Boring and Milling Machine



Tar Filter Installed at Beckton Gasworks

for horizontal or vertical mounting, the 4in brake is suitable for horizontal machines only. It can be wound for d.c. up to 500V (over 250V d.c. a small resistance is inserted in series with the coil) and for single-phase a.c. up to 500V, 50 c/s. On three-phase supplies the brake coil is connected across one phase of the supply. If required, a shaft extension of square section can be supplied so that the motor can be rotated by hand.

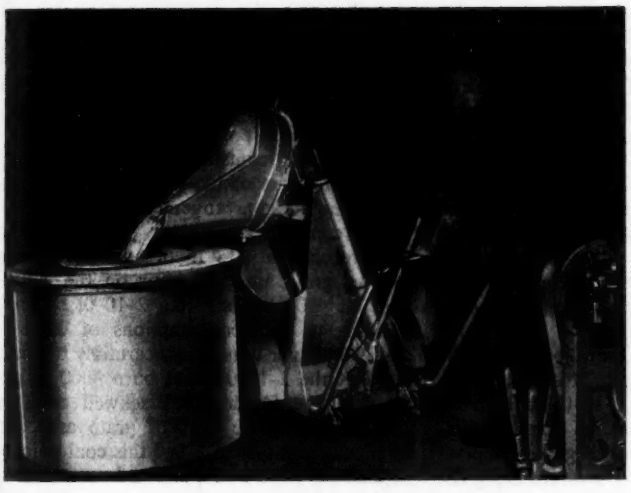
Hydraulic Lifting and Tilting Truck Ladle

We have obtained some details concerning the "Wellworthy" hydraulic lifting and tilting truck ladle, which is now being made under licence by the Monometer Manufacturing Company, Ltd., Savoy House, Strand, London. This truck has a carrying capacity of 200 lb aluminium and is intended for transporting metal from bulk melting furnaces to bale-out furnaces, die casting machines or spinning machines.

It is handled entirely by one man, lifting and tilting being performed by actuation of the pump handle, these being two distinct actions. The body may be lifted to any position on the traverse of the primary ram for filling, and as the height of pour from the bulk melting furnace decreases so the body may be lowered by operating a twist grip valve control situated at the top of the pumping handle.

For pouring, the ladle body is brought up to the extent of the primary ram traverse, and then by further action of the pump handle a secondary ram comes into operation. This, in conjunction with the tilting lever connected to a bracket on the body frame, produces the desired tilting action. Lifting and tilting can be performed speedily whilst the return action may be as fast or as slow as desired.

Fabrication is of steel with precision machined hydraulic components. The pump valve and oil reservoir are mounted on the chassis beneath the ladle body and the pump operating handle is placed adjacent to the control handle, giving easier manipulation to the operator. The whole is mounted on roller-bearing pneumatic-tyred wheels, which give general ease of movement.



Hydraulic Lifting and Tilting Truck Ladle

Glide Path Indicator for the Navy

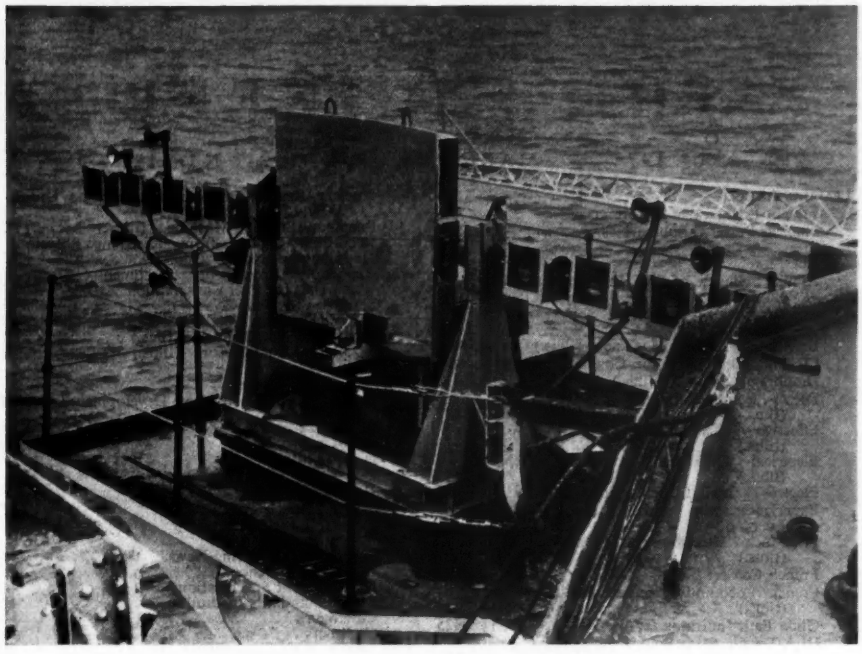
A glide path indicator has been developed for the Royal Navy which will supersede the manual signalling system at present used to land aircraft on naval carriers. The need for such equipment with the landing speeds associated with high-speed turbo-jet aircraft has become increasingly desirable in recent years and with the characteristics of future aircraft which are envisaged the reaction lags between the "batsman's" and the pilot threaten to render that method impracticable. The new equipment, which is effective in clear air by day or night, is basically simple and requires no responding equipment in the aircraft. It involves an optical system employing light sources and a large curved mirror, the angle of elevation of which is stabilised by gyro mechanism. During an approach the pilot watches the mirror and two lines of coloured lights which are placed on each side of it. These components can be seen in our illustration. Aft of the mirror and focused on it is another set of lights which respond to deck movement and produce a light "blip" in the mirror. The task of the pilot is consequently one of adjusting his vertical angle of approach so that the reflected "blip" and the bar of horizontal lights remain in the same plane.

The curvature of the mirror, which is in the form of a segment of a cylinder polished inside, makes the blob visible at all necessary angles in the horizontal plane. Hence the pilot can pick up the lights as he sweeps round to approach the carrier's stern.

The vertical angle at which the mirror is set is varied according to the type of aircraft landing-on in order that, as the pilot comes in on the flat beam of light, his undercarriage will be at precisely the right height above the carrier's stern just before he lands.

Since he cannot take his eyes from the device in the aircraft carrier, a translucent reflecting material is arranged on the windscreen of the aircraft. In this reflector appears a red, yellow or green light, which tells the pilot whether he is flying too fast, too slow or at the correct speed. These lights are actuated by the air speed indicator. Ultimately it is anticipated that all carriers will have one or more of these aids and they will be used, without gyro-mechanism, at Naval Air Stations.

The development of the equipment has been carried out at the Royal Aircraft Establishment, Farnborough.



The Mirror Landing Aid for Aircraft Carriers

French Coaster "Catenac"

The French coaster "Catenac," which is owned by Worms et Cie, Paris, and was launched in July of last year from the yard of Augustin Normand, completed her trials last month before entering her owner's Bordeaux–Havre–Antwerp–Hamburg service. This ship is of considerable interest as being the first merchant ship to be fitted with main propelling machinery consisting of a free-piston gas generator and a gas turbine. As far as external appearances are concerned, the form of the hull and the general design of the ship are in the main identical with earlier vessels, such as the "Nina" and "Pinta," built by Chantiers et Ateliers Augustin Normand and now operated by the Cie Générale Transatlantique.

The "Catenac" has the following main particulars :—Length overall, 208ft 5in ; length between perpendiculars, 194ft 10in ; breadth moulded, 30ft 6in ; depth moulded to upper deck, 18ft 5in ; draught, 13ft 9in ; load displacement, 1622 tons ; deadweight, 940 tons ; service speed, 12 knots, and machinery of 1200 h.p. The main machinery consists of two free-piston gas generators built by the Société Industrielle Générale de Mécanique Appliquée (S.I.G.M.A.), and two gas turbines, constructed by the Société Gale de Constructions Electriques et Mécaniques Alsthom, driving a single shaft through reduction gear supplied by the Ateliers et Chantiers de Bretagne. The "G.S.34" pattern gas generator consists externally of a cylinder, about 13ft 8in in length by 4ft in diameter, housing a pair of opposed diesel engine pistons of 340mm diameter, each driving a co-axially mounted compressor piston of 900mm diameter. Power generated in the diesel cylinder is absorbed in compressing air and the compressed air from the single-acting compressors passes into the scavenging chamber and through the diesel cylinder to the gas turbines. This combination of exhaust gas and surplus scavenge air is at a temperature of about 500 deg. Cent. and drives the Alsthom gas turbine at 9800 r.p.m., a speed which reduced to 220 r.p.m. at the propeller.

During trials a total of 1200 h.p. was developed with two gas generators and 700 h.p. with one in operation, while the following speeds were attained :—12·5 knots with the machinery developing 1250 h.p.; 11·8 knots with 890 h.p., and 11·1 knots with 670 h.p. The propelling machinery can be run on gas or fuel oil, and the installation weighs approximately 60·5 tons, including a spare generator, compared with about 69·5 tons for supercharged diesel machinery.

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FREIGHT LOCOMOTIVE PERFORMANCE

The longevity of British freight locomotives is almost proverbial. While the first-line express passenger engines of such famous pre-grouping railways as the London and North Western, the Great Northern, and the North Eastern have all been scrapped, and while the remaining passenger locomotives of Great Central design are relegated to very minor duties, large numbers of the contemporary freight engines not merely remain, but are entrusted with heavy and important service. The exigencies of high-speed passenger traffic will quickly lay bare the weak points in detail design of a locomotive, but in freight working, providing the engine will steam it is an ability to stand up to hard slogging at low speeds that matters, on any sort of fuel and with a minimum of shed maintenance. It is on such counts that engines like the Robinson "04" class 2–8–0s of the former Great Central Railway have stood the test of time. Although the design dates back to 1911 more than 250 of these tough old warriors are still in service to-day. Refinements in front-end design, including long-lap valves, brought a surprising turn of speed to some 2–8–0s built in more recent times, and we know of instances where the Stanier "8F" class of the former L.M.S.R. have run at more than 60 m.p.h. in passenger service. In time of war the 2–8–0 has a special part to play. During the emergency of 1914–18 many engines of the Great Central type were built for service in France with the Railway Operating Division, and in the second world war some locomotives of Stanier design were built for duties in the Middle East. Later in the war, however, when very large numbers of locomotives were needed in readiness for the invasion of the European continent, a new "Austerity" design of 2–8–0 was prepared for the Ministry of Supply. At a time when demands for materials were great and the choicest steels were needed for direct war weapons, those responsible for locomotive construction, whether for the Ministry of Supply or for railway service at home, had, largely, to make do with the leavings; and with the "Austerity" 2–8–0s in particular many new details of construction had to be adopted to suit the times. Even so the design seemed essentially sound, and since the war, with 730 of the engines on British Railways, we have heard very favourable reports of their general reliability in traffic, even though the maintenance costs, due to conditions existing at the time of their construction, may be a little higher than that of pre-1939 British 2–8–0 designs. The "Austerity" 2–8–0 was followed by a still larger engine, the "Austerity" 2–10–0, but only twenty-five of the latter were built.

It was thus with great interest that we received the latest bulletin from the Locomotive Testing Committee of the British Transport Commission, dealing with the performance and efficiency tests on these "Austerity" 2–8–0 and 2–10–0 locomotives. The two types have the same nominal tractive effort—cylinders, valve gear, coupled-wheel diameter and boiler pressure being the same in both. But the 2–10–0 has a considerably larger boiler, and a wide firebox having a grate area of 40 square feet, against the 28·6 square feet on the narrow grate of the 2–8–0. The ten-coupled engine has a lighter axle load—indeed, the heaviest loading occurs on the wheels of the tender: 14 tons, in comparison with a maximum of 13¼ tons on the locomotive. We were in some way prepared for the appearance of this bulletin, by a reference to the tests themselves in the bulletin dealing with the "Britannia" class "Pacific" engines; in that report was noted the ability of a larger grate to carry more clinker or ash from poor quality coal, before the air supply through the fuel bed becomes sufficiently restricted to affect steaming adversely. It was stated that this factor would be brought out in the bulletin dealing with the "Austerity" 2–8–0 and 2–10–0 classes. So it is, and most disturbing reading it makes, too. Both engines were given a general repair immediately before the tests and so, presumably, were in first-class mechanical condition; yet we read that the 2–8–0 as received was steaming poorly and it was necessary to reduce the blast pipe orifice from 5½in diameter to 4⅞in before it would perform satisfactorily. Unlike previous tests which we have described, this series does not appear to have been accompanied by any preliminary work on one or other of the stationary testing plants. Testing has been confined to road trials between Carlisle and Kilmarnock, using the mobile test plant of the former L.M.S.R. This point, we feel, is one of some importance in view of the very disappointing results from the 2–8–0. Previously certain engines which, when received for test, steamed poorly were subjected to careful analysis and experiment, with highly beneficial results, before undergoing full-dress trials. In view of the large number of these "Austerity" 2–8–0s in use on British Railways and the length of service they may give it is surprising to us that further preliminary experimenting was not done.

As it was, the 2–8–0 with the reduced blast pipe orifice gave what the bulletin terms a "satisfactory" performance on Blidworth coal but fell down completely on Grade 3B Blackwell. This latter could not be burned satisfactorily for extended periods, and a maximum steam rate of approximately 13,000 lb per hour was all that could be sustained for 45 minutes. The 2–10–0, on the other hand, proved to be free-steaming and the maximum steam rates quoted are 23,500 lb per hour with Blackwell and 27,000 lb with Blidworth. While on the face of it these results appear as a triumph for the larger boiler and wide firebox of the ten-coupled engine, it would have been interesting in the circumstances if details could have been given of the respective fire grates and draughting arrangements. With Blidworth coal the maximum steaming rates were reached at 113 lb of coal per square foot of grate area per hour on the 2–8–0, and at 109 lb on the 2–10–0, corresponding to coal consumptions of 3240 lb and 4360 lb per hour. It is certainly interesting that the 2–10–0 could burn 4000 lb per hour of the Grade 3B Blackwell coal, at 100 lb per square foot of grate area per hour, whereas on the 2–8–0 this coal quickly formed a heavy deposit of non-porous clinker which adhered hard on the firebars. When tests at heavier steam rates were attempted on the 2–8–0 it was found that after a short period a bed of incompletely burned carbon gradually built up above the clinker due to lack of primary air. The 2–8–0 seems to have been an unfortunate engine in other respects, since it was found impracticable to conduct tests at higher speeds than 40 m.p.h. due to rough riding. Having in mind the 730 engines of this class on British Railways, all relatively new, and the occasions on which they will be called upon to burn poor fuel, we feel that sustained research is called for, with closely analytical testing on one of the stationary plants, before the bulletin just published can be regarded as a final assessment of the capabilities of these engines.

NUCLEAR POWERED SUBMARINES

The launch, a few weeks ago, of the U.S. submarine "Nautilus," which is to have a nuclear plant for the generation of steam, and, which was discussed in our issue of February 12th by our American correspondent, introduces a new era in the conduct of war at sea which may well have important consequences for nations whose influence, prestige and safety have for generations rested on sea power. Atomic plants for surface ships may also be anticipated in the near future, in view of the contract recently awarded to the firm of Westinghouse, near Pittsburgh, to build a nuclear reactor "suitable for the propulsion of large naval vessels such as aircraft carriers." The plant is, in fact, intended for installation in one of the projected 60,000-ton supercarriers of the "Forrestal" class. Atomic plants for surface ships will, however, have results far less revolutionary than for submarines. They will certainly dispense with the need for fuelling bases or for the large number of tankers and their escorting vessels required to maintain a Task Force in a theatre of operations. But a submarine with an atomic plant will be transformed into an entirely new kind of vessel. The fact that the "Nautilus" will be able "to circumnavigate the globe without refuelling" is only an incidental advantage and affords no good reason for building a submarine at a cost of £10,000,000—a sum which does not include the heavy cost of her nuclear plant. Existing large submarines have all the surface endurance required. The revolutionary feature of this new ship lies in her ability habitually to operate submerged at high speed instead of merely using her power to submerge when the need arises, either for offensive or defensive purposes.

The Germans realised in 1943 the urgent need for underwater vessels of this kind when they found that radar detected U-boats on the surface both day and night. As a temporary measure they made use of the snorkel, or snort, which permitted the diesel engine to be used at periscope depth, but by the end of the war they had nearly completed four submarines each fitted with one Walther cycle turbine engine, using hydrogen peroxide as oxydant for fuel. The Allies—and presumably also the Russians—have been experimenting with these U-boats since the war, but the Americans, at any rate, have abandoned the Walther cycle engine in favour of an atomic plant, probably because of the inflammable nature of hydrogen peroxide. The "Nautilus" should be able to remain under water—subject to the endurance of the crew—for any length of time desired and to operate at 300ft, or at any other safe depth required, at a speed which is officially stated to be "more than 20 knots," but may well prove to be between 25 and 30 knots, depending on the power of her turbine engines. When this is compared with the endurance at the maximum practicable continuous speed of existing submarines submerged—a few hours at 5 or 6 knots—it will be seen that she does indeed, in the words of Admiral Carney, United States Chief of Naval Operations, represent "the beginning of a new chapter in the history of sea power." Moreover, as she will be independent of the snort—with which, together with a diesel engine, she is equipped for emergency and plant repair purposes—she will have the great advantage of being safe from detection by radar.

Much investigation and trial, however, will still be necessary before the navies of the world adopt this revolutionary type of vessel. Her large size—somewhere between 2500 and 3000 tons—will make her an easy target once she has come within range of the asdic installation of surface vessels. At speeds of 25 knots and over it will not be an easy task to control her depth keeping with the forward and after hydroplanes, nor to operate effectively her own asdic installation for locating the presence of hostile surface ships in her vicinity. She will carry her own air supply for the crew in the form of oxygen kept stored at high pressure, but the removal of carbon dioxide is a problem which has yet to be fully solved. Moreover, in the steam-operated British "K" class submarine of World War I the heat from the boiler room—which had to be shut off and evacuated when submerging—made conditions for the crew none too comfortable for some time after the vessel had dived. How will the crew react when the "boiler," or heat exchanger, is in permanent use when the vessel is submerged? These and other difficulties, apart from the need for navigational fixes by cross bearings from shore wireless stations or by the stars, are likely to necessitage the submarine coming to the surface—or at least to periscope depth—at fairly frequent intervals and thus losing the advantage of immunity from radar detection. None the less, the "Nautilus" seems likely to be a formidable antagonist, particularly if she can operate her asdic efficiently at these high speeds and can fire homing torpedoes at her target from a safe depth. There is also the possibility that our new anti-submarine frigates and other existing hunter-killer ships will have insufficient fuel to maintain what may prove to be a prolonged chase lasting over a period of days at speeds of 25 to 30 knots. Indeed, this need may well eventually compel the installation of atomic power plants in surface ships.

Obituary

SIR PAUL GUETERBOCK, K.C.B.

WE regret to record the death of Colonel Sir Paul Gueterbock, K.C.B., D.S.O., which occurred on March 8th, at Abbots Leigh, near Bristol. Sir Paul, who was sixty-seven, was a past-president of the Institute of Metals and managing director of Capper Pass and Son, Ltd., of Bristol.

Paul Gottlieb Julius Gueterbock was educated at Rugby and Trinity College, Cambridge, and entered the non-ferrous metals industry in 1908. In the years prior to the first world war he was concerned principally with researches into the alloys of lead and tin. Sir Paul served with the Gloucestershire Regiment throughout the first world war, being mentioned in dispatches and gaining the M.C. and the D.S.O. He commanded the 4th Gloucesters from 1924 to 1929 when he was promoted to the rank of Colonel on the Territorial Army General List. In 1947, Sir Paul was appointed an additional A.D.C. to the late King George VI, which appointment was renewed after the Accession of Her Majesty The Queen in 1952.

Following his war service, Sir Paul resumed his work in the non-ferrous industry, and for some time he was head of the research department of Capper Pass and Son, Ltd. Subsequently, he became managing director of the firm, in which office he continued up till the time of his death. In addition to his active participation in the work of the Institute of Metals, Sir Paul was a member of the council of the Institution of Mining and Metallurgy, and a past-chairman of the British Non-Ferrous Smelters' Association. He was created K.C.B. in 1949.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

BUREAUCRACY IN LOCOMOTIVE DEVELOPMENT

SIR,—The lengths to which you have been drawn in editorial comment in defence of Mr. Ell's recent quite unsubstantiated claims on railway timetabling, even to the extent of blaming the poor signalmen for the discrepancies between "exact" theory and actual practice, must go far towards convincing the impartial spectator of the weakness of your case.

Mr. W. B. Thompson's fears on bureaucracy expressed in the same issue are shared by far too many others for them to be airily dismissed, as you claim. In the engineering field, the dangers are well substantiated by the indifferent collection of mechanical horrors which it has evolved under the guise of "British Railways' New Standard Engines." No one could reasonably disagree with your contention that timetables should be adjusted to use existing locomotives to the best advantage. But surely when new engines are built to meet forthcoming requirements, as in the case of this particular series, should not every advantage be taken of available knowledge to design them for these specific tasks? The standard engines, on the other hand, were openly produced to cover so wide a range of tasks, that it is obvious that few, if any, of these can be performed with even reasonable efficiency.

Thus, indeed, does the one hand of bureaucracy inevitably disregard what the other hand is doing.

"PYROTECHNIC"

Manchester,
March 14th.

Books of Reference

F.B.I. Register of British Manufacturers. London: Iliffe and Sons, Ltd., Dorset House, Stamford Street, S.E.1. Price 42s.—This export reference-book is compiled by the publishers in close collaboration with the F.B.I.

Its seven sections include a buyers' guide which classifies over 6500 member firms under more than 5000 alphabetical trade headings, and full details of all the firms are given in a comprehensive alphabetical directory. Other sections provide useful information about trade associations, proprietary names, trade marks, &c.

Tatasachen und Zahlen aus der Kraftverkehrswirtschaft. Seventeenth edition. Frankfurt a.M.: V.D.A., Wirtschafts-G.m.b.H. Price 12 D.M.—This book gives a useful collection of data compiled by the Verband der Automobil-Industrie, the German equivalent of the British Society of Motor Manufacturers and Traders. It contains detailed production records of all German manufacturers making motor vehicles (including motor-cycles), trailers and automobile accessories, and, further, data about imports, exports, new registrations, &c., and information about the German road system with an interesting survey on road accidents and their causes. An "International Part" deals with production, import and export figures of all automobile producing countries. This well-compiled book ought to be of value, particularly for economists who are interested in questions connected with the motor industry and with motorised traffic.

Literature

Techniques of Technical Training. By H. R. MILLS. London: Cleaver-Hume Press, Ltd., 42A, South Audley Street, W.1. Price 10s. 6d.

THE technical training of men and apprentices was sadly neglected for a long time and perhaps a major war was necessary to give it the place it deserves. The author presents to his reader a very useful and practical outline of what is involved in efficient training so that an instructor may start on right lines and be able to awaken and maintain the interest of the trainee. Sir Arthur Fleming, in his Foreword, says that Mr. Mills possesses "a very sound knowledge of the theory and practice of teaching and very considerable practical experience and insight—a combination that is all too rare," while the author himself tells us that "this book is intended as a stimulus to the instructor to study his art," and it is felt that he has succeeded; indeed, we agree with him that a good instructor is, in fact, made, not born. Many of us have in the past suffered at the hands of instructors who, though likeable and extremely knowledgeable, failed to inspire either interest or zeal. In later years we may also have encountered university professors, specialists in their subject, who lacked the ability to awaken enthusiasm in their students, or to pass on some of their expert knowledge. Had they in their early days made a comprehensive study of the subject as set out by Mr. Mills in *Techniques of Technical Training* they themselves, as well as those they sought to instruct, would have greatly benefited.

To give a general idea of the scope of the book before us it should be mentioned that it is divided into ten chapters, the first of which indicates the background to training, pointing out the extreme importance of a good start and giving the new worker a pleasant introduction. The next chapter deals with the preparation necessary for the instructor to be able to present the subject in a sensible manner, realising how we all learn through the different senses, the actual presentation being described in Chapter III indicating as it does the part played by enthusiasm, good showmanship, a dramatic sense, a correct attitude and other qualities. We then pass on to the class he has to instruct (Chapter IV), the need for an understanding on his part of the student, the value of praise, as well as of healthy competition, and the ability to produce good class morale, comfort and activity. The great importance of correct assimilation is stressed in Chapter V, the process being likened to that of the digestion of food, the usefulness of questions and answers being instanced, as well as the desirability of having a clear understanding of what to avoid, and at the same time developing useful aids to the memory. Chapter VI covers the different means of testing, examining and reporting progress; the author considers the system of awarding marks to be very unreliable, and he prefers to grade men in comparison with one another. The subject of selecting men for appointment and promotion and the value of interviews are discussed. Experimental results (Chapter VII) have yielded valuable information about the results of trying to learn two subjects at the same time, about the relation of efficiency to fatigue, about the point at which saturation is reached, and the effects of good leadership, of a planned programme and of a careful grouping of students as opposed to haphazard methods. The remaining three chapters are devoted to the various methods of instruction and training aids, one (Chapter IX) being exclusively devoted to the place of the film in technical training. Finally, there is a useful bibliography. The foregoing should give a general idea of the ground covered.

Some of the author's conclusions deserve special thought. For example, he states that a lecture of an hour is far too long, and maintains that saturation point is reached after ten minutes of intensive study, and points out the value of breaking up a lecture by visual aids, demonstrations and questions. The value of a break in a long period of work has been proved by results, but the author draws attention to the fact that this very value is greatly increased by providing means for complete relaxation during the break.

Food for thought is to be found in a number of the assertions made, such as: "inattention is the instructor's sin"; "teach a little thoroughly rather than a lot superficially"; "one picture is worth a thousand words"; "attention is keenest at the beginning or end of a course"; "we should be really thankful for our forgetfulness, good memory is often forgetting unimportant things"; "a film should have a strictly limited objective." When preparing a course the idea of dividing into three sections of what the trainee must know, should know and could know is a very sound one, the time factor deciding whether it is possible to speak about the third category.

The author, in his preference for grading in order of merit rather than by marks, alludes to the Stannine grading, but he would do well to explain exactly what that grading is. Again, he evidently envisages interviewing being conducted by one individual, yet it is felt that when important decisions have to be made a small board of, say, three members is preferable. We agree that a good instructor should not mind confessing that he does not know the correct answer to an honest question, but he should always be ready to promise to find out before the next lesson. A "chancer" will rightly soon earn the contempt of a class.

The seasoned and successful instructor will find much to interest him in this book, and will not be slow to appreciate many of the suggestions made, and the would-be instructor will make a better start in his career by a careful perusal of its pages.

The Dynamics and Thermodynamics of Compressible Fluid Flow. Volume I. By A. H. SHAPIRO. New York: The Ronald Press Company, 15, East Twenty-sixth Street, 10, N.Y. 16 dollars.

THERE is now available a choice of substantial textbooks dealing with compressible flow to which is now added this latest treatise from America, written by an established worker in this field. Professor Shapiro presents this two-volume work as an introductory text in the subject as well as a reference work for some of the more advanced phases. The first volume begins with a section devoted to fundamental principles, including a twenty-page account of thermodynamics which is, to say the least, inadequate. Then follow chapters dealing with one-dimensional flows with various combinations of area change, heat addition and friction, and including an account of normal shock waves. The second half of Volume I is devoted to two-and three-dimensional steady flows which are either wholly subsonic or supersonic. The chapters devoted to subsonic flows present the method of small perturbations, the hodograph method and the derivation of infinite series solutions, while the methods given for supersonic flow include small perturbations and characteristics. Volume I concludes with a chapter on oblique shock waves, while Volume II, to come, will extend the treatment of supersonic flow to wings and bodies of revolution and also deal with mixed flows, unsteady motion and the flows of real gases as they are influenced by viscosity and thermal conductivity.

This outline of the contents shows that Professor Shapiro has produced a comprehensive treatise. The treatment is thorough, while most chapters contain a useful collection of unworked examples. There is an appendix containing the properties of the atmosphere and tables of compressible flow functions. The book is well produced and has a good index. It would certainly appeal to "students, engineers and applied physicists," for whom it is written, except that the price of £12 for the two volumes will be beyond the means of many members of these classes who will turn to alternative British books which, at one-third the price, are equally comprehensive and up to date. It will remain for our libraries to make Professor Shapiro's important book available for reference.

Welding, Brazing and Metal Cutting. Edited by E. MOLLOY. London: George Newnes, Ltd., Tower House, Southampton Street, W.C.2. Price 15s.

THERE are a number of books dealing in detail with the various branches of metal joining processes. This book provides an introduction to many of those classified as welding and brazing, and also metal cutting. The principles and practice of electric arc welding are well described in twenty-three pages, which include adequate data and useful sections on accessories and practical shop tests. Three short chapters discuss briefly the principles of "Argon-Arc" and "Unionmelt" welding, and equipment for stress relieving. One chapter of twenty-two pages outlines the principles of the various resistance welding processes, with data and tables quite adequate for a book of this nature. There are, however, a few incorrect or misleading statements, notably that, on automatic spot welders, pressures (which presumably should read "currents") are applied for controlled times as low as 5 cycles with contactors, or fractions of a half cycle with electron tube devices, and that the first transformer tapping always gives the highest secondary voltage. Two chapters of thirty-five pages describe thoroughly the oxy-acetylene welding of mild steel and also of most other ferrous and non-ferrous metals. In seventeen pages Chapter VIII deals with the bronze welding technique and its application to various steels, copper, brasses and, of course, to the most important question of the fabrication and repair of iron castings. Brazing is confined to two good chapters on the flame brazing of aluminium and the furnace copper brazing of steel, and to two pages on stainless steel. Two chapters of thirteen pages cover adequately the oxygen cutting and electric arc cutting of metals, and six pages are devoted to hard facing with "Stellite." In addition, there are forty-four pages giving a general description of shipyard welding and welding of automobile bodies.

The book contains a useful index, but no bibliography.

There is one criticism which must be

levelled against this book, which aims, according to the Preface, to assist the operator and others to master the techniques of the various hand and machine methods now employed. It has been written by a number of separate individuals or companies, many of whom are obviously competent to write on the subjects in which they are interested. However, there appears to have been very little attempt to co-ordinate the various chapters and to prevent a number of serious omissions, which might present to the uninitiated a very misleading picture of the processes in common use which he might like to master. For instance, the only reference to automatic arc welding is contained in four pages on "Unionmelt" welding, no mention being made anywhere of the conventional automatic metallic arc and carbon arc processes, both of which are widely used. Again, reference might well have been made to atomic hydrogen welding, which is being successfully used in many manual and automatic operations. Concerning brazing, surely one chapter might have been devoted to giving at least an outline of the complete family of brazing methods—torch, furnace, h.f. induction, resistance, salt bath and dip brazing as applied to a wide range of metals. The two excellent chapters in the book would then be seen in proper perspective as describing two rather specialised branches of a large family of brazing processes. Lastly, Chapter XVI might well have been enlarged to include other methods in the important subject of "hard facing."

Railroad Engineering. Vol. I. By WILLIAM W. HAY. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 60s.

THIS work, entitled *Railroad Engineering*, has been compiled principally for the use of students of the subject at the University of Illinois at Urbana, and aims, as the author explains in his preface, to present modern trends and developments, as well as those fundaments which have been long established. It goes without saying that this treatise discusses the subject from the standpoint of practice in North America; even so, we think it will be found of interest and value to those who wish to widen their knowledge of civil engineering as applied to the construction and maintenance of railways. The number of works on the subject is not large; indeed, it is stated that this is the first new book dealing with it to be published in thirty years. Such being the case, it would seem altogether reasonable to suppose that a modern approach to this important subject might with advantage be made available. The last book we recall and which may be said to cover generally similar ground is one also emanating from the University of Illinois, written by Clement C. Williams, entitled *The Design of Railway Location*, a review of which will be found in our issue of October 23, 1925, or almost thirty years ago. Turning now to Professor Hay's book, we may at once say that it provides interesting and instructive reading on a great many aspects of railway engineering, civil rather than mechanical, though the latter receives some attention. The book is divided into two parts; the first considers thirteen different subjects under the broad heading of "Principles of Location and Operation," and the second, a further fourteen under the heading "Principles of Maintenance and Construction." The mechanics of the subject are found in Part I, chapters six to ten. Chapter six discusses the well-worn subject of train resistance by considering largely the work done by Professor E. C. Schmidt, head of the department of railway engineering at Urbana, and another well-known experimenter, W. J. Davis, whose formula was adopted for use in connection with the remarkable tests carried out in 1939 by the Association of American Railroads with heavy, high-speed passenger trains. This is a well-composed and informative chapter on this particular subject.

Steam locomotives receive attention in the following chapter, seven, not from the point of view of the designer, but rather from that of the user, i.e. tractive force is considered, which is, of course, what railway operation requires. The author gives attention to the factor of adhesion and to methods suggesting different authorities for determining the tractive force available at speed and, in doing so, refers to the Kiesel formula and to a method put forward by the Baldwin-Lima-Hamilton Corporation of Philadelphia, formerly better known as the Baldwin Locomotive Works.

There is a good general drawing of a modern steam locomotive with all parts numbered to correspond with an index of names. Electric locomotives are fully described in the following chapter, eight, and diesel-electric power receives attention in chapter nine. The information given in each case is adequate for the purpose and well supported by diagrams showing pulling powers at speed. The author received the assistance of experts on these forms of motive power. The remaining four chapters in the first part of the book are given up to acceleration and deceleration, tonnage rating, problems of gradients and location procedure. The second part of this book is devoted to the actual road itself; that is to say, the road bed, rails, sleepers (ties), turnouts, crossings, earthworks required and drainage. As we have already pointed out, American practice is the foundation upon which the author has built his work; it is, nevertheless, valuable, because, while there may be differences in the practice followed by different railways, the fundaments remain very largely the same irrespective of the location of the railway. We have been rather especially interested in perusing the chapter on the design and manufacture of rails, which is informative. The weights of the rails mentioned are heavier than we use here and reach, in some instances, as much as 155 lb per yard.

The advantages offered by the use of heavy section rails are indicated by experiments carried out on the Illinois Central Railway, where two 20-mile sections of track, each subject to almost identical natural and operating conditions, were laid with 112 lb and 131 lb rails. The heavier rail cost 1800 dollars more per mile in place than the lighter 112 lb track, but at the end of four years, with a total of more than 115 million gross tons over the track, the average annual cost of maintenance was found to be 210 man-hours less per mile of track, and during the period the number of ties (sleepers) renewals ran about twenty-five less per mile of track with the 131 lb compared with the 112 lb rail. The further information given concerning rails comprises a complete table providing full detailed dimensional particulars of rails in use.

The chapters on rails, joints and track fastenings should be of value to railway civil engineering students and, quite possibly, executives in charge of railway construction, and can be therefore recommended. It is both well compiled and illustrated. Every chapter is supplemented with lists of references and what the author describes as "Suggested Readings." The book ends with a complete index of contents, extending over the last twenty-four of the 469 pages comprising the entire volume.

SHORT NOTICES

Industrial Electronic Engineering. By Wells L. Davies and Herman R. Weed. London: Sir Isaac Pitman and Sons, Ltd., Parker Street, Kingsway, W.C.2. Price 55s.—This book, which is one of the Prentice-Hall Electrical Engineering Series, is written by two Americans and is intended for use by advanced students. It is assumed that the reader is familiar with a.c. circuit theory, the elementary theory of electronic circuits and elementary differential equations. More advanced mathematics is developed in the book, as required, in the chapters on servo mechanisms, regulation and radio-frequency heating. Apart from a chapter on gas tubes which are widely used in industry no attempt is made at the presentation of background material, which the reader is assumed to possess. Throughout the book the emphasis is on basic methods of analysing and solving practical problems rather than on descriptions of circuits for specific applications.

Dangerous Goods. By the Belgian National Committee of the International Cargo Handling Co-ordination Association. London: I.C.H.C.A., 7, Victoria Street, S.W.1. Price 7s. 6d.—This booklet has been produced, as a result of a study of the handling of dangerous cargoes, by the Belgian National Committee of the International Cargo Handling Co-ordination Association with the collaboration of Dr. Jules Aeby. In the preamble reference is made to existing authoritative material on the subject and an explanation of the plan followed in preparing the elementary guide for those who handle and transport dangerous goods. The various products are listed alphabetically under their usual denomination, together with their chemical formula, and where the use of a common denominator was not possible synonyms have been used and these are listed in an index. Associated with each product is a column giving a description of its characteristics by means of a signal code using certain conventional signs to denote the nature of the product, for which purpose seven classifications have been adopted. In the third column the standard or regulation packing or container is mentioned and the fourth column advises as to stowage.

BOOKS RECEIVED

Textbook of Servomechanisms. By J. C. West. London: English Universities Press, Ltd., Saint Paul's House, Warwick Square, E.C.4. Price 25s.

Understanding Other People. By J. M. Fraser. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 3s.

Metallurgy of the Rarer Metals. No. 1: *Chromium*. By A. H. Sully. London: Butterworths Scientific Publications, Ltd., 88, Kingsway, W.C.2. Price 35s.

Metallurgy of the Rarer Metals. No. 2: *Zirconium*. By G. L. Miller. London: Butterworths Scientific Publications, Ltd., 88, Kingsway, W.C.2. Price 45s.

Electrical Installation Work. Second edition. By T. G. Francis. London: Longmans, Green and Co., Ltd., 6 and 7, Clifford Street, W.1. Price 12s. 6d.

History of Steam Road Vehicles. By C. St. C. B. Davison. London: Her Majesty's Stationery Office, York House, Kingsway, W.C.2. Price 3s. 6d.

Dictionnaire Technique Anglais-Francais, Chauffage Industriel. By I. Dusnickis and P. Chaumelle. Paris: Dunod, 92, Rue Bonaparte (VI). Price 750F.

Bessel Functions and Formulæ. Compiled by W. G. Bickley. London: Cambridge University Press, Bentley House, 200, Euston Road, N.W.1. Price 3s. 6d.

Fundamentals of Structural Analysis. By A. A. Jakkula and H. K. Stephenson. London: Macmillan and Co., Ltd., St. Martin's Street, W.C.2. Price 33s. 6d.

Engineering Electronics. By G. E. Happell and W. M. Hesselberth. London: McGraw-Hill Publishing Company, Ltd., 95, Farringdon Street, E.C.4. Price 60s.

The Aircraft Engineer's Handbook, No. 4.—Instruments. By R. W. Sloley and W. H. Coulthard. Sixth edition. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 30s.

Engineering Metallurgy: A Textbook for Users of Metals. Fourth edition. By B. Stoughton, A. Butts and A. M. Bounds. London: McGraw-Hill Publishing Company, Ltd., 95, Farringdon Street, E.C.4. Price 53s. 6d.

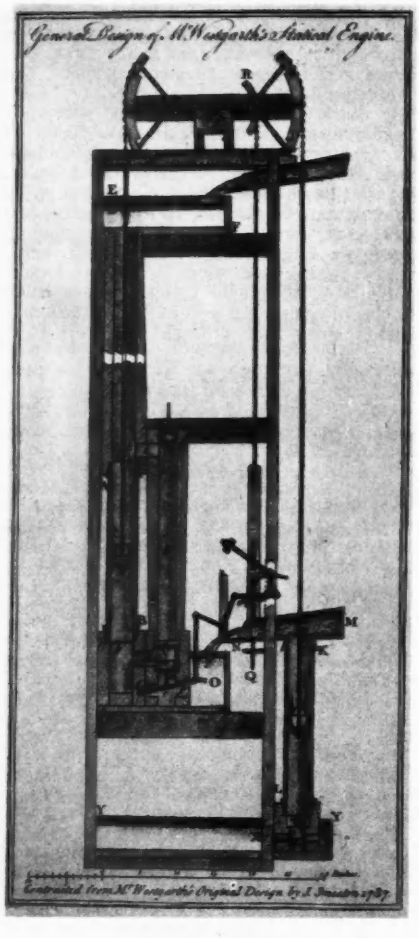
Bi-Centenary of the Royal Society of Arts

By A. C. HARTLEY, C.B.E., F.C.G.I., M.I.C.E., M.I.Mech.E.

This Society celebrates its bi-centenary next week and a full programme of events has been arranged which will recall the antiquity of the Society and its achievements during two centuries. A new history of the Society will be published which will describe in full detail the wide variety of fields in which these achievements have been made and the part it has played in the life of the nation. In this article, the principles underlying the Society's activities and how they have influenced the work of engineers in the past will be described. Reference to its present-day activities will be followed by the suggestion that engineers as a whole might derive increasing benefit for themselves by taking an interest in the work of the Society and its future.

THE 200th session of meetings of the Royal Society of Arts was opened with H.R.H. The Duke of Edinburgh, K.G., President of the Society, in the chair, on November 18, 1953. The inaugural address was delivered by The Earl of Radnor, K.C.V.O., Chairman of Council.

The importance of the position to which the Society has now attained could not have been made more abundantly clear than by the presence of The Duke of Edinburgh only



William Westgarth's Pumping Engine, 1787 : Downward Flowing Water Acting Upon a Piston Operated a Pump

five days before he set out on the Commonwealth Tour with Her Majesty The Queen, who for four and a half years before her accession to the Throne was President of the Society. The strength of the links with the past was emphasised when the President referred to the continuous association of the Royal Family with the Society for well over a century, and when the Chairman of Council took for the subject of his address "The First President, Viscount Folkestone," whose lineal descendant he is.

The Society's First Century

In 1753, William Shipley, a Northampton drawing master, published locally a proposal "for raising by subscription a fund to be distributed in Premiums for the promotion of improvements in the Liberal Arts and Sciences, Manufactures, &c." Failing to obtain this support locally, he came to London and enlisted the influential and enthusiastic support of Viscount Folkestone and Lord Romney, and with eight others, at a meeting on March 22, 1754, founded "the society for the encouragements of arts, manufactures and commerce in Great Britain." This, it should be realised, was nearly thirty years before mechanical engineering as a profession came into being, mainly as a result of the development of the rotative steam engine, and it was sixty-four, ninety-three and 117 years respectively before the foundation of the Institutions of Civil, Mechanical and Electrical Engineers.

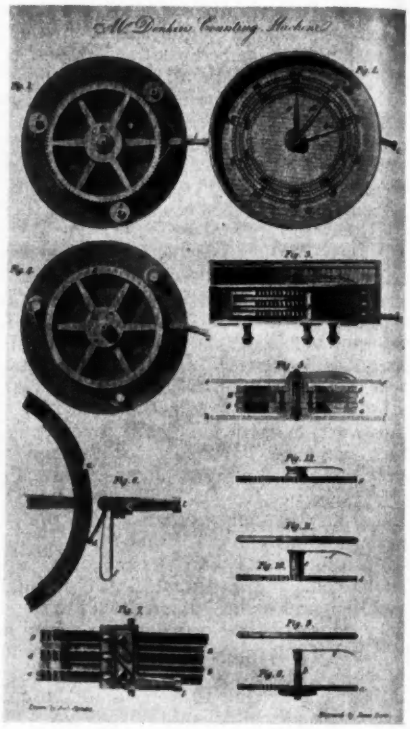
The method of "encouragements" followed by the Society was the offering and awarding of "Premiums" on the principle that "Encouragement is much the same to Arts and Sciences as culture is to Vegetables : they always advance and flourish in proportion to the rewards they acquire and the honours they obtain." At their very first meeting, the eleven founder members agreed to offer four prizes, two for simple technical purposes and two for children's drawings. These received an immediate response, and during the next few years a long list of awards was offered for the improvement of hundreds of practical objects and purposes. Some of these bore immediate fruit in the successful development of the objects for which the prizes were put up, but by far the greatest benefit lay in their broad psychological effect, for they taught people to realise that improvement was possible in most things which they had hitherto considered to be perfect.

The membership of the Society had reached more than 2500 by 1762 and it is clear that it must have supplied a great want right from the beginning. Among the signatures in the first subscription book are those of Horace Walpole, Thomas Chippendale, Joshua Reynolds, Samuel Richardson, Robert Clive, Edward Gibbon, Robert Adam, William Hogarth, Samuel Johnson, John Howard and many other famous men.

The influence of the Society's work was not only felt in Great Britain, but also overseas, largely due to the sound technique which was evolved for the conduct of the prize competitions as a result of experience with the first "Premium" list. It is interesting to note that each individual offer was subjected to the following conditions :—

(1) Whether the object for which the prize was proposed was an important one with more than temporary or local significance.
(2) The precise requirements to be stipulated as the basis of competition.
(3) Whether the prize should consist of money or a medal.
(4) How many prizes should be offered and what should be their value.
(5) How long the time limit should be.
(6) The best means of certification.
(7) Whether the competitors needed to be given any preliminary information on the subject of the offer.
(8) Whether any permanent record in the form of a written account, drawings, or, in the case of machines, a model, should be required.

It is no wonder that the Society developed rapidly with such carefully worked out con-



Brian Donkin's Revolution Counter, 1819 : On Completion of a Revolution by the Mechanism Controlling the First Digit the Mechanism Controlling the Second Digit was Moved One Step Forward

ditions and that six principal standing committees had to be formed to deal with the offers under the headings of Agriculture, Chemistry, Polite Arts, Manufactures, Mechanics, and Colonies and Trade.

The industrial field was small during the early years of the Society's existence and it devoted much attention to pioneering developments in agriculture. These are described in Robert Dossie's *Memoir of Agriculture*, published with the approval of the Society, in which he describes how useful the Society was in the initiation of inventions by referring to a prize offered in 1766 for a machine for slicing roots, so that they would cease to choke the animals they fed. Until this prize was offered, no one had thought of designing such a thing, but once the idea was propounded a simple effective machine was very soon designed, and won for its inventor the Society's Gold Medal.

Awards offered by the Society led to the development of drain-ploughs, seed drill, threshing mills, reaping machine, &c. The Society did great and fruitful work during this

period and became a national agriculture centre, anticipating the Board of Agriculture by forty years and the Royal Agricultural Society by eighty years.

Besides encouraging new processes, the Society encouraged the production of new crops, timber and other raw materials, and the manufacture of chemicals and drugs. It also took considerable interest in mining and established an assay furnace and equipment in the kitchens of the Society's offices in 1757 for assaying specimens of British ores. Awards were given for the discovery of manganese and chrome-ironstone, and a fifty-guinea prize enabled William Smith in 1815 to publish his Mineralogical Map of England and Wales and to become known as "The Father of British Geology."

Besides promoting the discovery of minerals, the Society did a good deal to assist in the winning of them and offered prizes for many years for improved devices for bringing minerals to the surface. Probably the most interesting of these was the endless chain device, invented by Thomas Arkwright, of Kendal, who received a prize of twenty-five guineas in 1801. The sea was not overlooked as a further source of raw materials, and the Society's prizes encouraged the invention of the gun harpoon, thus providing a source of oil before mineral oils were discovered.

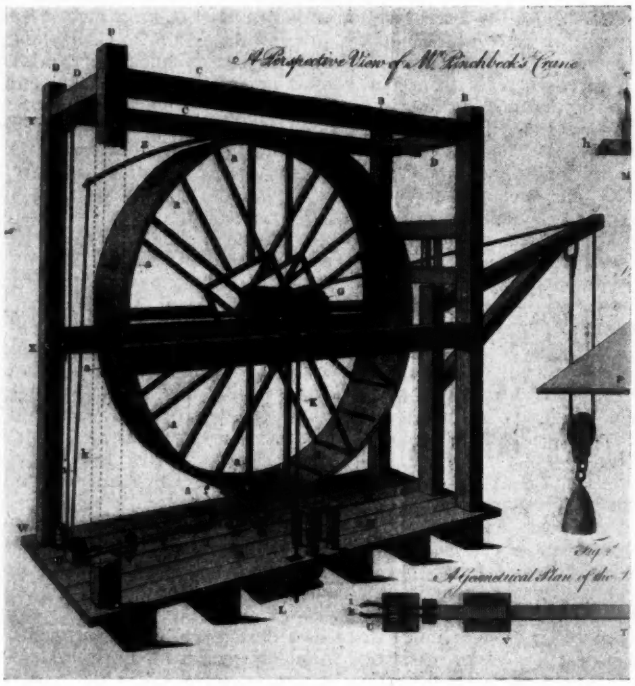
The Society had meanwhile extended its interest to the British possessions overseas, the most important of which at the time when the Society was founded were those on the mainland of North America. The Committee of Colonies and Trade had Benjamin Franklin for its chairman in 1761, and he was a most enthusiastic supporter of the Society, doing much to further its activities in the American colonies. The famous expedition of the "Bounty" originated from the Society offering a prize for the successful transplanting of the bread-fruit tree to the West Indies.

As the industrial revolution gained impetus the premium system encouraged mechanical invention to such an extent that the Committee of Mechanics had become probably the busiest of the six principal Standing Committees by the early part of the nineteenth century.

An overall leadership was established in the field of humanitarian principles and the welfare of the workers—which even the most enlightened people were quite insensitive to at that time. The ventilation of mines, respirators, tests for poisons, fire fighting, and the development of chimney sweeping equipment, which would make unnecessary the use of boys, all engaged the Society's attention.

Turning now to the Society's work in connection with industrial power and industrial equipment, when the Society was formed, steam power was a thing of the future except for a few crude engines used for pumping mines and for machines which had to be "work'd by windy power or wat'ry force, Or by circumambulating horse." Many awards were offered for wind and tide mills and money was spent on special apparatus for tests, including a "model mill race with artificial race and waste trough," and on making a system for "measuring as accurately as possible the power created." These were not very successful, but in 1769 a bounty of fifty guineas was given to William Westgarth for a hydraulic pumping engine in which a downward flowing column of water pressing the piston of one cylinder was made to operate a pump, which forced another column upwards, as may be seen from our first illustration. The Society made several awards for improvements in the mechanism and control of water wheels, which became the mainstay of many branches of industry.

Here we illustrate Pinchbeck's Crane (1767) and Brian Donkin's Revolution Counter (1819), both of which received awards from the Society.



Pinchbeck's Crane, 1767 : Fitted with Automatic Brake to Prevent Running Back of the Walking Wheel

The Society was, however, slow to take an interest in the development of the steam engine, and although they had their attention drawn to a model for converting alternate motion of the Newcomen engine into rotary motion in 1768, and a reference was made to a steam engine they examined early in 1769 as appearing to be a very ingenious application of the expensive force of steam and meriting the further attention of the Committee in order to determine its power, the Minutes of the Society give no indication that any action was taken. It did, however, offer an award in 1783, just after Watt's second and third patents, for "increasing the quality or force in steam engines with less fuel," but although the offer was renewed each year for half a century, it was never claimed. Awards were, however, made for improvements in the design of boilers and safety valves and further developments, culminating in the award of a Gold Medal to William Siemens in 1850 for the regenerative condenser.

By this time industry was so much better organised and able itself to reward inventors that the Society's offers of premiums became a progressively less effective form of "encouragement." It was therefore decided that the best service the Society could render to inventors would be to hold meetings at which discoveries and their applications could be described and discussed.

The Second Century

Meetings and Publications.—During its earlier years the Society had concentrated so thoroughly on "encouragement" rather than mere instruction, that it had often been criticised for its weakness in straightforward propaganda. It was only in 1783, after thirty years of stimulating others, that it realised that much of the benefit of the successful activity stirred up by its premiums was being lost, because those who did not compete were not informed of the results. In 1783, therefore, it began to publish an annual volume of *Transactions*, in which the experiences of prizewinners were recounted, but even then the series more or less lapsed fifty years later.

The holding of meetings had, however, become so successful by 1852 that the Society began to publish a weekly *Journal*, which was continued without a single break for nearly ninety years. It thus amply made up for its early deficiencies, and the weekly *Journal* was followed by the present fortnightly *Journal*.

In addition to the holding of meetings for the reading of papers, meetings are held for the delivery of lectures, and there can be few prominent technical and scientific discoveries of the last century whose introduction to public use have not been assisted in this way by the Society. Notable lectures have been Graham Bell's description of the telephone in 1877, which included the first public demonstration of this invention in London ; Hiram Maxim's account of the first flight in a heavier-than-air mechanically propelled machine in 1894 ; reports by Marconi of some of his inventions in 1901 and 1924 ; and, in recent years, Sir Howard Florey's classic account, with Sir Alexander Fleming in the chair, of the discovery of penicillin in 1944.

Exhibitions.—At about the same time as the institution of meetings, the Society began to take an interest in the holding of exhibitions, due largely to the fact that Prince Albert had become President of the Society in 1843. He took a great personal interest in the application of science and art to industrial purposes, and this led to many new developments, including a competition in 1845, held for designs which might be shown in exhibitions. The first small exhibition was held in the Society's Lecture Hall in March of 1847, and it is interesting to quote the following statement from the introduction to the catalogue : "It is a universal complaint among manufacturers that the taste for good art does not exist in sufficient extent to reward them for the cost of producing superior works ; that the public prefer the vulgar, the gaudy, the ugly even, to the beautiful and perfect. We are persuaded that if artistic manufactures are not appreciated it is because they are not widely enough known. We believe that when works of high merit of British origin are brought forward they will be fully appreciated and thoroughly enjoyed. We believe that this exhibition, when thrown open gratuitously to all, will tend to improve public taste." Upwards of 20,000 people visited this exhibition, in spite of the comparative smallness of the room in which it was held, and it fully achieved its object of not dictating to the public, but of training its taste.

Manufacturers had needed a good deal of

persuasion to lend their goods for this first exhibition, but they clamoured to get into the second exhibition held the following year, to which 72,000 people came, and into the third, to which over 100,000 came. These exhibitions led naturally to the Great International Exhibition of 1851, with which the name of the Prince Consort will always be associated. The success of this Exhibition led to the idea of a more permanent type of exhibition and the Royal Society of Arts can thus claim to have had a considerable share in the inception of the Victoria and Albert Museum.

Education.—The Society's interest in education began, as has been mentioned, with its first list of premiums, which included prizes to encourage the teaching of art to children, but in 1852 it began to take a more direct and definite interest in educational matters, and it formed a union of the institutions for the education of adults of the working classes which were founded in many parts of the country on the model of those established by Dr. Birkbeck in Glasgow and London. In 1856 the Society set up an examination system to meet the needs of members of these mechanics institutes. The syllabus included mathematics and mechanical sciences, in addition to literature and the fine arts. This originated the system of carrying out local examinations from a common centre, and it has continued since 1854 to conduct the leading examinations in commercial subjects, and these have now reached enormous proportions. Less than twenty years later, examinations in technology were introduced for reasons expressed in a report read to a meeting in 1872 : " It has long been acknowledged that if this country is efficiently to maintain its manufacturing supremacy in the markets of the world, the technical education of our artisans must be improved, and the Council of the Society of Arts are of opinion that technological examinations (which do not form any part of the systems either of the Universities or of the Government) would be of great use in furtherance of this end.

" The Council are of opinion that it would be of public advantage if the Society of Arts were to supplement the existing examinations of the Science and Art Department by organising examinations in the science and technology of the various arts and manufactures of this country, to be conducted by examiners capable of testing the practical knowledge and skill required in the application of the scientific principles involved in each art or manufacture."

These examinations proved to be yet another of the Society's successful pioneering efforts, and they were handed over in 1879 to the City and Guilds of London Institute, in the foundation of which the Society played a very important part.

Present Activities

Having now described the principles underlying the Society's activities which have influenced the work of engineers in the past, reference will be made to present day activities. These continue to be the conducting of examinations, the conducting of meetings, delivery of lectures, the publication of the fortnightly *Journal* and the organisation of special conferences and exhibitions.

The work of the Society for the overseas Empire has now been merged in the Commonwealth Section, which has its own regular meetings and lectures. H.R.H. the President, said at the opening meeting of the 200th Session : " The most impressive feature of this Society, to my mind at any rate, is that after all these years, 199 so far, the original pioneering atmosphere is so strongly apparent. There is no obsession with the past ; the Society remains essentially forward-looking and practical. The Royal Society for the Encouragement of Arts, Manufactures and Commerce is not just concerned with doing things in a different way, which some people call progress ; it is concerned with doing practical things in better ways, which is real progress. It is not concerned with ' Art for Art's sake,' but it is concerned with the application of art to the improvement of the design of manufactured articles, and this duty is as important now, if not more so, as it was in the eighteenth century.

" Next year the Society starts its celebrations of its two-hundredth anniversary, and to emphasise its concern for the future and for the practical things of life it is going to organise as one of the features of the celebrations a competition. The idea is that entries should show—to quote the exact phrase—' the practical aspects of life in this Earth in the year 2000,' and the purpose is eventually to stage an exhibition of the entries which, by a combination of informed guesswork and wishful thinking, will give the general public some idea of what to expect in forty-six years from now, assuming, of course, that nothing drastic has happened in the meantime to upset things.

" In the statement of the conditions under Hints to Competitors, it says : ' The year 2000 has been chosen by the Society as a focus for speculation because, while a period of forty-six years would allow for the origination and development of entirely new features in life, it is short enough to enable competitors to envisage the world as they or their sons or daughters would like to see it."

H.R.H. The President's statement makes it clear that the Society intends to continue to apply the principles which have hitherto enabled it to play such an important part in the national life. It has long since attained a position which enables it to attract papers and lectures from leaders in all branches of the sciences and the arts, and membership of the Society will thus enable engineers to keep abreast of developments not only in all fields of engineering, but will also enable younger engineers and technologists to fill the alleged gap in their education which has been the subject of much discussion during the past few years. It is one to which my attention has frequently been drawn as a result of my experience on the Councils of professional Institutions and on the Governing Body of the Imperial College. I refer, of course, to the criticisms that the curricula of Universities and Technical Colleges in this country tend to produce engineers with too narrow a field of view, and without appreciation of the humanities. References are frequently made to the systems of education adopted in the United States, Switzerland and in Germany, but it is becoming more and more apparent that those systems are by no means ideal for their own conditions, and would be even more unsuitable for our own British conditions.

In my Presidential Address to the Institution of Mechanical Engineers in 1951, I stated : " The ideal method of training an engineer will continue to provide material for discussion as long as there are engineers to be trained ! The curricula of schools, universities, technical colleges and technical institutes, and also the requirements of our own and sister professional Institutions for corporate membership, will remain constantly under review. But, whatever changes may be made to meet changing conditions, I consider it fundamentally important, and indeed imperative, that all young men should be able to experience the influence of sound leadership at all stages in their education and training so that they may be inspired to use imagination and initiative and to develop self-reliance. It is our senior members who must provide this leadership each in his own sphere of activity and in the contributions he makes to uphold the high professional status of our Institution. Our lectures, meetings, papers and discussions provide, outside the necessarily limited contacts of our working lives, the great opportunity for the wider sharing of our experiences."

Having now had the privilege of serving on the Council of the Royal Society of Arts and of delving into its past achievements to prepare this article, I suggest that the young engineer can keep abreast of the wider developments in engineering by taking an interest in the work of the Society. During the last and the current session, he would have been able to hear papers or lectures on the following subjects : " Cheaper Building : the Contribution of Modular Co-ordination," " The Use and Abuse of Fuels," " British Inland Waterways To-day and To-morrow," " Improving Coal Production," " Contemporary Role of Industrial Standards," " Material Handling and Processing, Past and Present," " Scientific Appliances in the Services," " Kitimat Hydro-Electric Power Development Scheme," " The Safety Factor in Construction," " The Seed Crushing Industry," " The Work of the Wright Brothers for Aviation," " History and Achievements of Sanitary Engineering," " Safety on the Railways," " Safety on the Roads," " Safety in the Air," " Safety in Ships," " Engineering Developments in Central Africa."

I also suggest that the engineer's interest in a wider education and greater appreciation of the humanities can be stimulated by the Society far better than by trying to introduce these subjects into his already overloaded curricula. I am supported in this opinion by the viewpoint of the councils of the three engineering Institutions They have constantly advocated in recent years, when making recommendations upon the future of technological education, that it was vital for the young engineer to have as wide an appreciation as possible of the arts, as well as of the sciences. For instance, a close association of students of all departments in a teaching establishment is desirable. I am convinced that the Society has a part to play in this whole respect. For example, there were papers or lectures on : " Science of Musical Instruments," " 100 Years of the Victoria and Albert Museum," " Royal Portraits and Ceremonies, Some New Discoveries in Westminster Abbey," " Century of Photography," " Story of the Indian Army," " Cecil Rhodes," " Kuwait," " Furnishing Fabrics of the Past 200 Years," " The Arts," " Manufacturers and Commerce, 1754/1954," to quote only a few.

The strength of the Royal Society of Arts has been stated to " lie in the fact that it has been a pioneer in many fields, always willing to hand over the main responsibility to any duly authorised body, which quite frequently came into being as a result of the Society's efforts, yet always looking for other ways in which it might further worthy causes." H.R.H. the President, has emphasised that the Society remains forward looking and will encourage real practical progress and leadership. Engineers who now decide to take part in the Society's work will find a truly British way of broadening their education and imagination, encouraging their initiative and increasing their capacity for invention. They will thus become able to play a fuller part in the life of the whole Commonwealth.

Electrical Engineers' Exhibition

No. I

THE third Electrical Engineers' Exhibition, organised by the Association of Supervising Electrical Engineers at Earls Court, was officially opened on Tuesday, March 16th, by Sir Henry Self, Deputy Chairman (Administration) of the British Electricity Authority. Compared with last year's show the exhibition has doubled its size. There are over 180 exhibitors, which is more than seventy above last year's total. The exhibition will be open from 10 a.m. to 7 p.m. to-day and to-morrow, which is the closing day.

Switchgear provides the main theme of this year's exhibition and, apart from the exhibits shown on the individual stands of various firms, examples of the industry's products are displayed in "avenues" devoted to heavy and light switchgear. Some of these equipments are being shown for the first time.

Besides the manufacturers there are among the exhibitors a number of Government Departments and research and trade associations. The British Electricity Authority is staging a display to show the growth in the demand for electricity from 1920–52 and to illustrate some of the achievements of the electricity supply industry since it became nationalised.

The Department of Atomic Energy, which is taking part in this exhibition for the first time, is presenting a display of models and photographs indicating progress towards the use of nuclear reactors for power generation. One of the models shows the experimental nuclear power station being built at Calder Hall, Cumberland, as it will appear when finished. On each side of the central turbine house and its associated control centre and workshop, there is a graphite-moderated uranium reactor. The reactors are gas cooled and the heated gas generates steam in four vertical boilers installed around each reactor. A second model shows the construction of the reactor itself.

The British Electrical and Allied Industries Research Association (E.R.A.) is showing, mainly by photographs and literature, something of the services that it renders to the electrical industry, with particular reference to the evolution of switchgear. One section of the stand is concerned with the development of specialised equipment for circuit breaker research from 1920 to 1930, and in the post-war years, and reference is made to some of the early experimental circuit breakers which were developed in the 'twenties and have been widely used since then.

Among the organisations taking part in the exhibition are the British Electrical and Allied Manufacturers' Association, the British Electrical Development Association, and the Cable Makers' Association.

Ferranti, Ltd.

Transformers, meters, indicating and industrial instruments and domestic appliances are being shown by Ferranti, Ltd., Hollinwood, Lancs. This company has recently introduced a new form of high-speed testing equipment for a.c. single-phase meters (Fig. 1), and a section of this testing equipment is being exhibited. It is a self-contained test plant and its function is to expedite meter adjustment without sacrificing the accuracy demanded by B.S. 37.

Normally, the test plant as illustrated in Fig. 1 is suitable for the calibration of twenty meters at a time, under the control of one tester, but it can be extended to accommodate 100 meters and five meter testers.

Calibration is done by comparing the speeds of the meters under test with the speed of a sub-standard meter, which is in this case a precision two-disc, balanced-torque meter thermostatically controlled at a constant temperature. The lower disc is used as the driving and braking disc. The upper disc, which has 200 gear teeth cut on its periphery, acts as a light shutter, interrupting light falling on a photo-electric cell, the output of which is amplified and applied in two different ways.

The first method consists of driving a synchronous motor coupled to a light-interrupting disc, thus giving a beam of light of high intensity which can be used on high loads to test stroboscopically meters carrying the usual patterned disc. This lamp is arranged on a system of rails so that it can be placed over any meter. In the second method another synchronous motor is geared to drive pointers, the rate of count being proportional to the sub-standard speed, thus making every counter a slave sub-standard. The counters are mounted on a panel below the meters under test.

To enable one sub-standard to be used on all kinds of meters which have differing constants and stroboscopic markings, a decade current transformer is interposed between the secondary of a multi-range c.t. whose primary is in series with the meters under test, and the sub-standard. A known fraction of the load current flows in the primary of the decade c.t. with a variable number of turns and, since the secondary turns are fixed, the secondary current (and hence sub-standard speed) is variable. Any meter with full-load speeds between 12 and 48 r.p.m. and carrying any stroboscopic pattern between 100 and 200 divisions can be tested without any alteration of the sub-standard.

The complete equipment comprises a test set and a test bench. The cabinet on the left of Fig. 1 houses the test set, which is arranged as a number of panels: they are, from top to bottom, an instrument panel; a sub-standard meter and decade transformer on a withdrawable chassis (the knobs of the decade transformer switches can be seen); the controls for current, voltage and power factor on a fixed panel; a small withdrawable chassis on which can be mounted a wattmeter for checking the equipment, and an amplifier on a withdrawable chassis. The test bench on the right of the test set carries two rows of twenty meters which are connected by compressing spring-loaded plungers. By feeding each meter through a separate voltage transformer, the meters can be tested with the shunt links closed and without removing terminal covers. The method of connecting the meter is simple, no leads being required. Of the forty meters, twenty on the upper row are warmed prior to testing, while the twenty meters on the lower row are being calibrated. The counter display can be seen mounted on a panel below the meters under test.

Calibration consists of stroboscopically testing the meters on high loads, and timing the meters on low loads using the counters. The counters are used in a similar way to stop watches in the conventional stop watch and wattmeter method; it is found that one tester can start twenty counters in sequence before the first meter has completed many revolutions on low load, whereupon the counters can be stopped in sequence. There is, of course, no need to steady the load when either strobing or timing, as any variation in load reacts identically on both sub-standard and meters under test. Generally, the errors on twenty meters can be determined on low loads to an indicated accuracy of one part in a thousand or better, in three or four minutes.

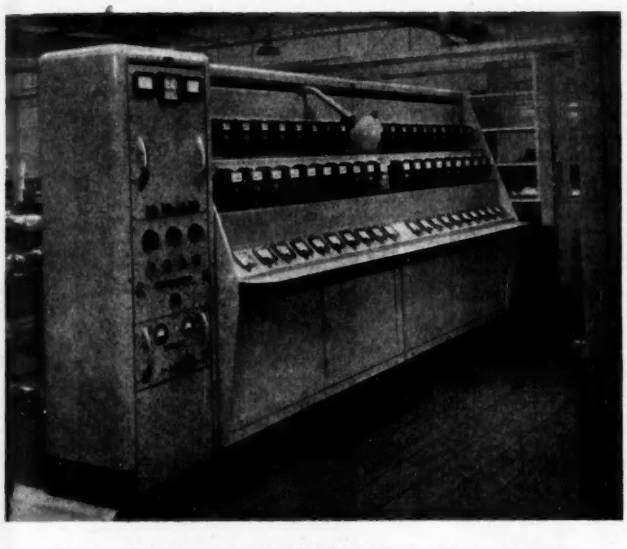


Fig. 1—High-Speed Test Set for Single Phase Meters—Ferranti

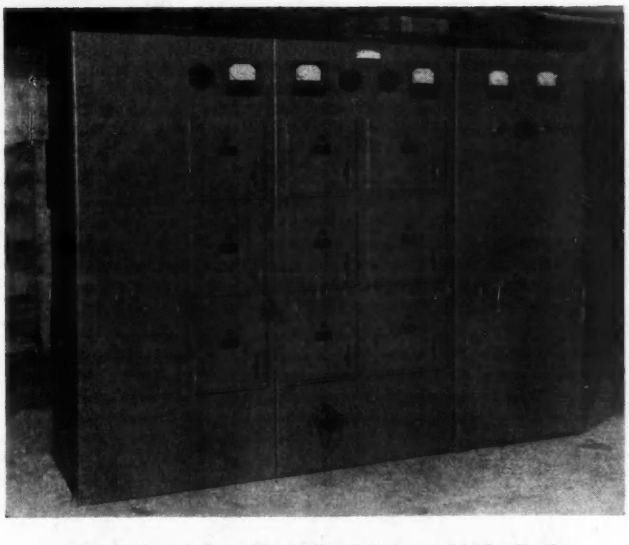


Fig. 2—Low Voltage Distribution Switchgear Cubicle—Brush

Brush Electrical Engineering Company, Ltd.

A high-voltage, weatherproof, outdoor oil fuse-switch is shown on the stand of the Brush Electrical Engineering Company, Ltd., Loughborough. This equipment has a rating of 60A at 11kV and a breaking capacity of 250MVA. It incorporates striker-pin cartridge fuses in an air-filled compartment. These fuses operate in conjunction with triple-pole, coupled, oil-immersed switches to give "all-phase" trip operation. On the busbar side and on the feeder side of the fuses the oil switches have quick-make and quick-break action, and a separate switch is provided for earthing the fuses. Mechanical interlocks prevent access to the fuses except when they are in the earthed position. The equipment is designed to be coupled to outdoor

ring-main isolator units by a compound-filled busbar chamber.

In the " Switchgear Avenue " the company is showing an example of its cubicle switchgear for 440V distribution. This exhibit consists of a single cubicle (the central cubicle shown in Fig. 2) housing six triple-pole-and-neutral switch-fuses of quick-make-and-break design. These switch-fuses carry r.c. cartridge fuse links rated at 25MVA and complying with the requirements laid down in B.S. 88 for category " AC5 " equipment. On the panel there are two ammeters and two three-way ammeter selector switches, arranged so that the current in any one of the six feeder circuits can be measured. The cable end boxes are inside the cubicle and they can be arranged for top or bottom entry, as required.

BRITISH THOMSON-HOUSTON COMPANY, LTD.

A prominent exhibit in the " Switchgear Avenue " is an end phase unit of a B.T.H. three-phase, 220kV, 5000MVA " Shuntarc " oil circuit breaker, thirteen of which are on order for the State Electricity Commissioners, Victoria. The design of these equipments is generally similar to that of the " Shuntarc " 275kV, 7500MVA circuit breakers which are being supplied to the British Electricity Authority for the Super grid. The prototype of this equipment was described in our issue of June 1, 1951, page 707.

Each phase unit has a convex lens-shaped tank which gives a 50 per cent saving in oil volume over the conventional cylindrical tank. To give high acceleration to the moving contacts, and thus ensure quick make-and-break movements, torsion bar springs are incorporated in the design, and attention has been given to the reduction of inertia and friction of moving parts.

The oil-filled bushings are of standard B.T.H. design with concentric internal insulating cylinders and compression type porcelains. Ring type current transformers can be accommodated. Operation is by compressed air, the mechanism being housed in a weatherproof cubicle fitted to the breaker tank.

A comprehensive series of tests at 220kV has been carried out on a three-phase 5000MVA circuit breaker (Fig. 3) at the Fontenay Testing Station of Electricité de France. The tests included line dropping up to 375 miles, the breaking of magnetising and reactor currents, instantaneous auto-reclosing and short-circuit tests. In addition, an exacting series of short-circuit tests, up to 100 per cent rating by the unit method of testing, has been completed at the Switchgear Testing Company, Manchester. The manufacturer states that this testing programme has proved that, whatever the short-circuit duty, the total short-circuit break time does not exceed three cycles, and that the inclusion of linear switching resistors makes the breaker suitable for installation anywhere in a high-voltage system irrespective of the restriking voltage severity.

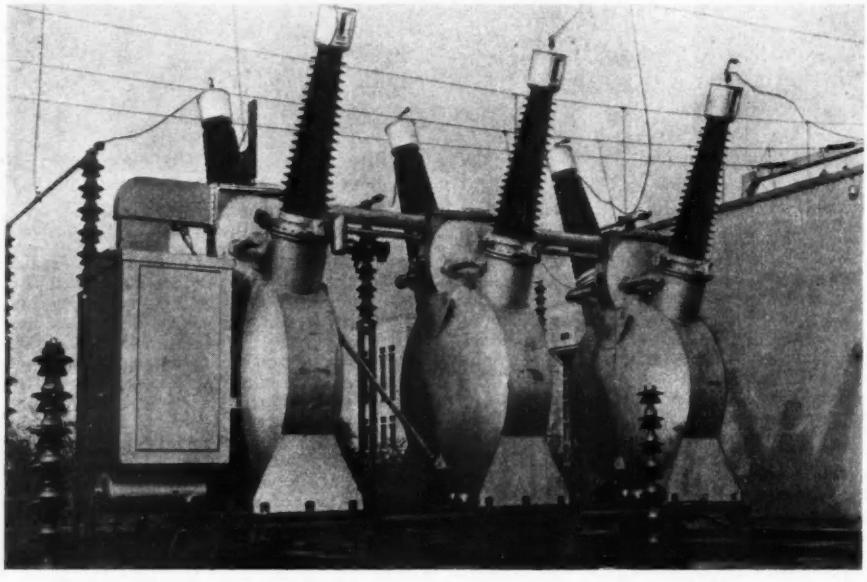


Fig. 3—" Shuntarc " Oil Circuit Breaker During 220kV Line Dropping Tests at Fontenay, France—B.T.H.

CROMPTON PARKINSON, LTD.

Examples of the range of " Klosd " (totally enclosed) squirrel-cage induction motors complying with British Standard outputs, shaft sizes and fixing dimensions are shown by Crompton Parkinson, Ltd., Crompton House, Aldwych, London, W.C.2. This range of motors covers ratings from ½ h.p. at 750 r.p.m. up to 25 h.p. at 3000 r.p.m., including ratings at 1000 and 1500 r.p.m.

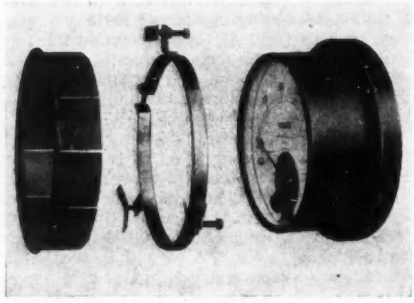


Fig. 4—Arrangement of Flush Mounting of Standard " Projecting " Switchboard Instruments —Crompton Parkinson

All the motors are totally enclosed and fan cooled except the smallest motor, which is totally enclosed without fan cooling. The copper wire of all the stator windings is insulated with a polymerised synthetic enamel, with Micanite slot insulation. After drying the stator is treated with a synthetic resin varnish and baked, whereupon the varnish polymerises and sets hard, making the windings permanent and rigid at all working temperatures.

The company is also showing a new form of 7in and 10in circular scale indicating instruments with circular barrel and flange, designed for either projecting or flush mounting. By the addition of a circular bezel with a clamping band (Fig. 4) the standard projecting instrument can be adapted for flush mounting. The base of the instrument is provided with tapped holes and the projecting meter can be secured to the panel from the back, either by screws or by studs and nuts.

The winding, movement and other components are mounted on an enamelled pressed steel base plate ; the cover is in enamelled pressed steel, the glass window being bedded in with cement and secured by clips. A gasket between the base plate and the cover makes the instrument dust and damp proof. These provisions apply to both moving-coil and moving-iron instruments. The instruments comply with the current B.S. 89.

In " Switchgear Avenue " the company is showing an example of its " ALA " metalclad switchgear for electricity supply and industrial substations. This class of switchgear has vertical isolation, with the circuit breaker mounted on a withdrawable truck. Side-blast baffle-pot arc control chambers are incorporated in these circuit breakers. The busbars and connections are air insulated. These equipments are available in rating up to the following maximum values :— 11kV service voltage ; 1600A continuous load current ; 500MVA breaking capacity.

CANTIE SWITCHES, LTD.

Examples of " Minunit " distribution switchboard cubicles are shown by the maker, Cantie Switches, Ltd., Bromborough, Cheshire. A typical " Minunit " cubicle is illustrated in Fig. 5.

The equipment is flush-fronted, built up of unit switches and switch-fuses, and is capable of being modified quickly and easily. The framework and housings are made of steel channel sections, with pressed steel covers, preformed and tooled to standardised dimensions. Cubicle sections can be assembled to provide multiples of a basic aperture size. to allow for the mounting of circuit breakers, contactors and instruments, &c. Normally, the back-to-front depth of these cubicles is 13in and, since all component assemblies and terminals can be made accessible from the front, the cubicles are well suited for flush-fitting in corridor spaces or recesses. By incorporating a disconnect assembly it is possible for a switch or switch-fuse up to 60A capacity to be withdrawn complete from the front while the cubicle remains alive.

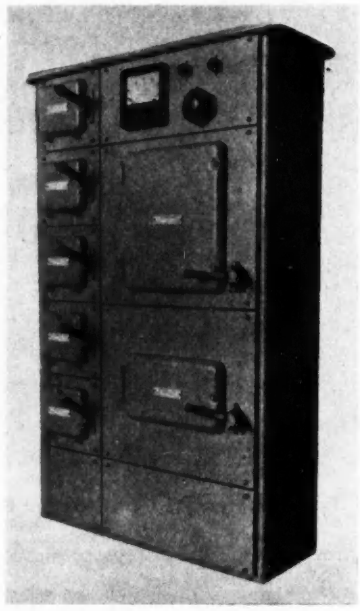


Fig. 5—" Minunit " Distribution Switchboard— Cantie Switches

Up to 60A rating the switches and switch-fuses mounted on these switchboards are of " Minunit " design, all sizes being identical in physical dimensions and occupying one basic aperture ; the switch is a completely enclosed, rotary movement and has a high load-breaking performance. For current ratings between 60A and 500A switches and switch-fuses of the Cantie heavy-duty range are used ; they incorporate the characteristic " bolt-lock " operating mechanism.

The switchboards are fitted with a drip-proof hood and dust protection is provided.

(*To be continued*)

Effective Utilisation of Material

By FRANK NIXON*

No. II—(*Concluded from page 401, March 12th*)

In this paper, which was read by Mr. Frank Nixon before the Institution of Production Engineers, Derby Branch, December 14th, and abstracted herewith, the author discusses the ways in which design, development, research, scale of production, and the forming methods adopted can dictate the effectiveness of material utilisation in prime movers.

Development.—The development department is of particular importance in the case of machines and prime movers. In these fields the function of the development engineer is to test the product to discover its weaknesses and by eliminating them to increase its reliability and its life and its specific performance.

The prototype of development engineers was Richard Trevithick, who in 1804 broke away from the tradition of the heavy and cumbrous atmospheric engines of Boulton and Watt and introduced high-pressure steam. In one leap he multiplied the power output of a given size of engines several times, and not only made railway locomotion possible, but pioneered it as well. This work caused about as big a stir as that of the gas turbine engine to-day.

Returning to the aircraft engine, the overhaul life of the civil " Merlin 724 " engine was raised by development from 600 hours to 1250 hours, for an increase in weight of only 70 lb, and only a small increase in cost. This engine is one of the latest of a long line of basically similar ones of 27 litres capacity which started in the last war as a 1000 b.h.p. engine and finished at nearly 2000 b.h.p., again largely through development.

Another good example of development is found in the Nimonic alloys which are used for turbine blades. Table I shows how during the

TABLE I—*Development in Nimonic Alloys*

Alloy	Temperature for fracture in 100 hours at x tons per square inch	Corresponding increase in thermal efficiency	Corresponding increase in thrust per pound of air consumed
	Deg. Cent.	Per cent	Per cent
80A	880	—	—
90	910	2·6	8
95	940	4	16

past few years the strength at temperature has been increased to give an effective rise in operating temperature of about 60 deg. Cent., which enables the thrust per pound of air consumed to be increased by 16 per cent for the same weight of engine.

Research.—It is unfortunate that, in this country at least, there exists a good deal of misunderstanding of the true meaning and function

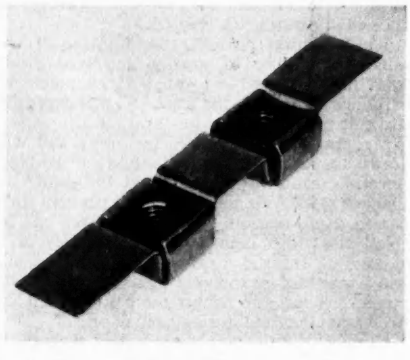


Fig. 5—Automobile Body Cage Nuts

of research, as much amongst research workers themselves as in the minds of practical engineers. This has led to confusion and overlapping, doubt and suspicion, and some lack of co-operation.

Some researchers have tended to weaken the faith of engineers by trying to provide quick answers to practical problems when they would have been better occupied in seeking fundamental solutions. It is not appreciated as it should be how narrow is in fact the gap between the production engineer and the fundamental research worker, and efforts to fill this gap by so-called researchers is tending to result in a good deal of redundancy.

Much of the most successful research has been carried out by men of practical outlook. It is interesting to look for a moment at the work of the past few decades, which has led to enormous improvements in material utilisation.

For instance, it is about 100 years since the

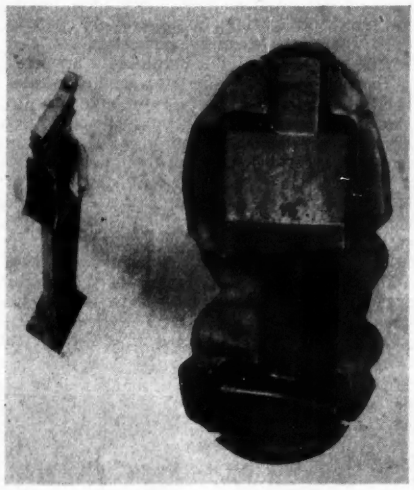


Fig. 6—" Dart " Turbine Blade

phenomenon of fatigue was first recognised by Robert Stephenson and others.

Then, in 1871, Wohler published his work on endurance tests under reversals of stress. But it required the impetus of the first world war to bring about an intensification of research effort, and the practical application of it to design. Other allied researches were made on the stress concentration due to sharp corners and oil holes, and on the effects of surface finish, notably by Professor Coker, Dr. A. A. Griffith and others. Most of this work was inspired by the needs of the aircraft engine, and a good deal of it was in fact carried out under the auspices of the Aeronautical Research Committee. If we look back at textbooks of engineering design of thirty to forty years ago there is no mention at all of the importance of adequate fillet radii, good surface finish, and freedom from cracks, and illustrations of engines show a frightening lack of any sort of radius at shoulders in keyways, &c. In fact, even more recently during his apprenticeship, the writer was once taken seriously to task by a foreman because he had not removed the radii from the root of a keyway, and produced a fitting key with dead sharp edges !

This work, by enabling the designer to work with a more accurate knowledge of stresses and hence with a lower factor of safety, has led to a lightening of structures generally with, in the aggregate, an enormous saving in material.

Of even greater importance has been the very great increase in reliability which has come about in many fields—machine tools, presses, motor-cars, railway wagons, aircraft engines, and so on, which indirectly has meant again better material utilisation.

Manufacture

Here we come to the section of primary interest to the production engineer. Every aspect of production management and engineering is concerned, and while these cannot have the same influence as design upon material utilisation, they play a very big part in the ultimate cost of the product. While the high performance, the light weight, and the reliability of the " Avon " engine, for example, are due in the main to the effects of the design, development, and research departments, the relatively low cost is due in the main to the manufacturing side, which has made a most important contribution to the other aspects too, by finding ways of forming and fabricating materials normally considered to be " impossible." Although the designer may be setting the pace, it is the production engineer who maintains it, as much to-day as 180 years ago, when John Wilkinson's boring mill allowed steam engine development to go forward. It may be remembered that he bored a 50in diameter cylinder to a tolerance equal to the thickness of an old shilling, and later improved his technique so that the tolerance on a 72in bore was not greater than the thickness of a thin sixpence.

Rate and Scale of Production.—Considerable responsibility rests upon the production engineer and management alike, to ensure that the choice of machinery and methods, and the type of tooling, are properly matched to the scale of production. There has of late been a good deal of misunderstanding here, due in the main to a too loose use of the terms " increased production," large-scale production," and " mass production." As a consequence, the special techniques of design and tooling and production which have been developed to meet the needs of the motor-car and ancillary industries, for example, are too often held up as models for all to copy.

The greater part of British industry is in fact not employed on mass production at all, which is perhaps a good thing, since it gives full play to our genius for extemporisation and flexibility. This has an important and perhaps somewhat unexpected effect upon material utilisation in minimising scrap and wasted effort due to modifications. For instance, in the case of large bomber aircraft, during the war, the productive man-hours per pound of aircraft were almost identical for similar British and American machines. As modifications became necessary to overcome defects, or to meet tactical or strategic needs, they were introduced quickly and smoothly into the British aircraft, without interrupting the production flow or reducing the output. In the States the planned " mass production " lines were so rigid that the factories had to go on producing obsolete aircraft which were then shipped hundreds of miles away to modification centres, where the new parts were fitted and the old thrown away.

At the opposite end of the scale a free and unfettered outlook, capable of turning away from the orthodox and getting right down to fundamentals, can save enormously by resisting the temptation to spend unnecessarily on equipment of high capacity and to use common sense

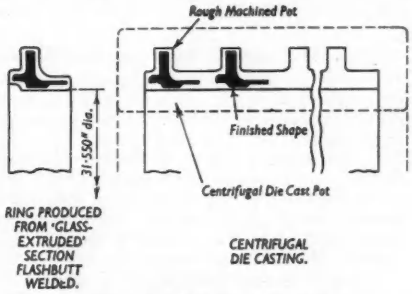


Fig. 7—Extruded and Cast Rings

instead. The double cage nut shown in Fig. 5 is a good example. Planned along textbook lines, this item, which is required in tens of thousands, would be made from steel strip, on a battery of roll feed and dial feed presses costing about £3600, with tools costing about £500, and at a rate of, say, forty per minute. It is actually produced at the same rate, on a battery of four fly presses costing, say, £140, with tools costing about £30. By using offcuts, which would be impossible on the automatic machines, the selling price is considerably below that of the fully-tooled job. Perhaps the greatest scope for improved flexibility is in the sheet metal field, where, following the lead of the motor body manufacturers, high tooling costs have come to be regarded as commonplace, and in consequence inevitable and acceptable. The possibilities here will be dealt with later.

In this connection a speech by Mr. Gordon McGregor, president of Trans Canada Airlines, at the recent dinner of the Society of British

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Aircraft Constructors, is worth quoting. Dealing with the success of the British aircraft industry in overseas markets for civil aircraft, he said: "Manpower is such an expensive commodity in the United States that it is becoming increasingly necessary to go to any length to conserve it. . . . This condition is driving the American manufacturer into fantastically large investments in tooling. Where vast production quantities are involved no harm is done. . .(but) these advantages unhappily vanish where the production of large civil aircraft is involved. The total number of any one type is unlikely to exceed 200 or 300; yet, having been driven into a massive investment in tooling, the manufacturer finds it economically difficult to abandon a design in favour of one more advanced. . . On the other hand, the lower cost of manpower in this country makes possible its greater use, with a consequently smaller investment in the tooling specific to any one aircraft type. A manufacturer in Great Britain could undertake the production of a comparatively small number of any one type, without risking the financial loss of a large amount of scrapped tooling."

It is as well to bear these remarks in mind when one is approached by an American salesman trying to recover the costs of developing his wonder machine by selling some abroad.

Choice of Method.—No manufacturing process which offers an advantage in any way can be ignored, and in consequence we find that most available processes are employed to a greater or lesser degree.

We find then, in the aircraft engine, forgings and drop stampings in high-tensile and in high-temperature alloy steels machined all over; precision die-forged blades in a wide variety of materials, machined only on the roots; sand castings, die castings, centri-castings, centri-spinnings, shell mouldings, and precision castings in light alloy, iron, steel and high-temperature alloys; hot extrusion, impact extrusions, pressings, spinnings and fabrications in light alloy, alloy steel, stainless steel and high-temperature alloys; brazings by torch, salt bath, induction and furnace in a variety of alloys; weldments by arc, shielded inert gas metallic arc, torch, spot, stitch, seam and flash butt.

Such a great diversity is only possible in a fairly large organisation employed on a high-quality product where performance is the primary concern. The task of the production engineer is to ensure that each process is employed efficiently, in the right application, and on the appropriate scale. In fact, the wide variety does not so much entail expensive equipment as a broad knowledge of skills and techniques. The claims put forward for any new process are viewed most critically, and in many cases the chief value of a new process has been to provide a spur to a fresh analysis of the shortcomings of the existing method.

Perhaps because the aircraft engine manufacturer has had to become a master of all trades he is well qualified to comment on the questions which are so much occupying management and production engineers to-day. Spurred on by the needs of the engine, he has in several vital instances been compelled to adopt processes which have normally been operated by specialist trades and to develop them, in an extremely short space of time, to a pitch which the expert has stated was impossible. This has been achieved by a refusal to accept statements without proof, by a straightforward approach to the problem.

In fairness to some members of the specialist trades, it must be said that in the first instance the new developments, as of precision forging and precision casting, could only be justified when applied to expensive materials, but even then it has required the uninhibited approach of the enthusiastic amateur to achieve success. This will be best illustrated by taking a few examples, and in order to put the matter into correct perspective it is appropriate to mention here that over 30 per cent of the finished engine is made from forgings, 5 per cent from bar, over 40 per cent from castings, and 10 per cent from sheet and tube. The overall utilisation figures average 22 per cent for forgings, 44 per cent for castings, and 50 per cent for sheet metal parts.

Forging.—The chief influence of the aircraft engine industry here has been due to its insistence upon absolute cleanliness of the metal, accurately controlled forging to give the most appropriate grain flow, and withal the development of materials of ever-increasing strength, which has intensified considerably the task. For instance, ultimate strengths of 65–75 tons per square inch for nitriding crankshaft steels, 100 tons per square inch for case-hardening steels for radial engine connecting-rods, and 85 tons per square inch for case-hardening gear steels, were normal for the engines of the last war. Machining and finishing all over were, of course, essential, as much to provide the highest possible resistance to fatigue as to reduce weight to a minimum. For example, the ("Bristol") radial engine master rod weighs 9¼ lb and has been machined from a forging in 100-ton case-hardening steel weighing 42 lb, a material utilisation of 22 per cent. This figure needs to be regarded in light of the fact that the rod is transmitting over 1000 b.h.p.

Fig. 8 shows the light alloy forging and the finished compressor rotor of the "Derwent" engine. The material utilisation is 48 per cent. In the axial engine the turbine and compressor blades present a special set of problems, due to their shape and the materials from which they are made. The difficulties of producing accurately thin aerofoil sections, having varying degrees of camber and twist according to the still limited but growing experience of design and performance, in light alloys, stainless steels and high-temperature alloys, have naturally led to a number of different solutions, both in this country and in the States.

With blade shapes and methods still in a somewhat fluid state it is perhaps a little too early to be definite about the ideal solution, and since there is in addition a wide variety of design practice in the form of root fixing, it is possible that more than one method may persist. In the author's personal opinion, however, there is little doubt that precision forging of the aerofoil will always play a big part.

This is one of the cases where the engine manufacturer has had to master a trade and point the way. This is exemplified by the turbine blade of the "Dart" engine (Fig. 6), which is forged to size on the aerofoil and on the platforms, so that these areas require no machining other than the radiusing of the leading and trailing edges after the flash has been clipped off.

Precision forging of less difficult shapes and in less difficult materials and to somewhat wider tolerances is, of course, well established. Losses occur between bar and forging due to the flash, scale, tonghold, test piece in the case of aircraft engine parts, and parting or shearing. These may amount to 30 to 40 per cent according to shape.

Another interesting example of progress in the wrought materials field is shown in the adoption of the Ugine Sejournet process for the extrusion of sections in stainless and alloy steels. The gas turbine engine, being essentially cylindrical, employs a fair number of circular flanges, which are welded on to casings. These flanges have been turned from cylindrical forged or cast rings, with a material utilisation, of fairly expensive metal of about 22 per cent. By making rings of extruded section, coiled and flash-butt welded, the overall utilisation has been increased to about 36 per cent and there has been a reduction in overall cost (Fig. 7).

The extrusion process, too, holds out considerable promise of greatly improved yields from ingot to usable form, a development of particular value in the case of the expensive strategic materials.

Mention must be made, too, of rolled and drawn shapes, where the utilisation can be high. Aerofoil sections can be rolled in lengths of stainless steel, with a loss of only 4 per cent from bar to blade section. Complex shapes can be cold rolled to a high degree of accuracy, with a loss of from 3 to 7 per cent. The only additional loss in applying these forms to compressor blades, gun trigger mechanisms and the like is that incurred during parting off.

Casting.—That castings are not in general use for highly stressed moving parts is due in the main to a widespread distrust which can usually be traced back to some unfortunate experience, such as that never-to-be-forgotten occasion when, as a child, the author dropped his new toy revolver and the casting shattered. Castings cannot always be produced to the dimensional accuracy and thinness which is dictated by the insistence upon lightness. They find their widest application, therefore, in light alloy static castings, where the effect of dimensional errors is not so great; to iron castings which can be machined all over; and to precision castings in high-temperature alloys for smaller

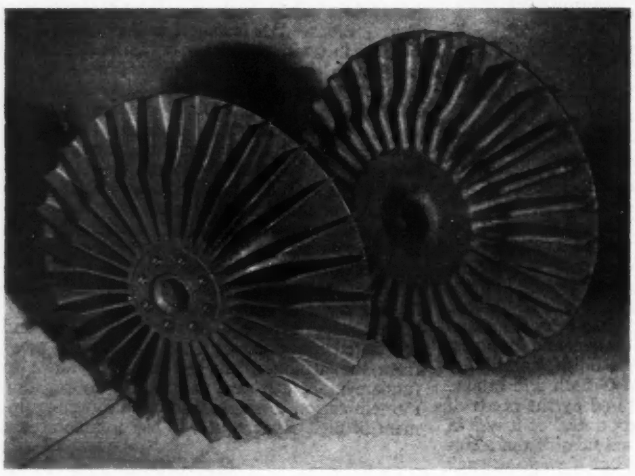


Fig. 8—Compressor Rotor and Blank for the "Derwent" Engine

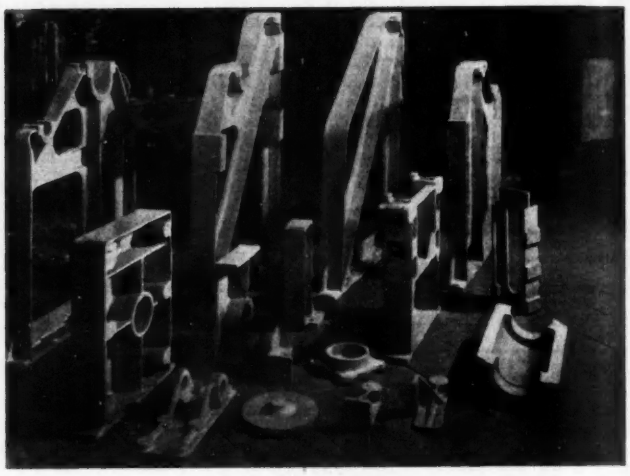


Fig. 9—Recent Examples of Castings in Steel

static components, such as nozzle guide vanes.

The economic advantages of being able to use as-cast parts for other components than these are so great that it is not surprising to see in the foundry industry to-day greater activity than for a long time past. We have seen during recent years the development of lost wax (e.g. Austenal and Trucast) and frozen mercury investment casting, shell moulding, the Shaw process, plaster moulding, permanent mould casting of ferrous alloys, and so on. In the main, however, these have been mould making rather than founding methods, and while they have undoubtedly led to improvements in accuracy and cost, improvements in the quality of the castings have in most cases been incidental. Fortunately the need for fundamental work on the metallurgical and founding sides is being appreciated more and more widely, and it is pleasing to note that considerable improvements have already been obtained, whilst others are pending, both as regards the accuracy of bigger castings, and the physical properties and reliability of smaller ones.

The argument usually adduced against castings is that they are unreliable because of the difficulty of ensuring freedom from undesirable inclusions, porosity due to shrinkage and gas, coarse structure, hard and brittle spots, shrinkage cracks, and so on. One of the main functions of forging is in fact to minimise the effect of such defects in the as-cast ingot.

By systematic attack upon the basic causes of these defects considerable advances are being

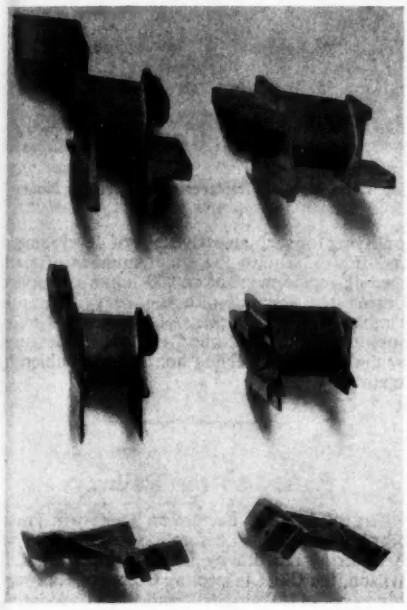


Fig. 10—Nozzle Guide Vanes

made. The Qualcast permanent mould process, for example, is producing castings completely free from porosity, with fine grain and with a mirror finish, if required. Cast crankshafts for motor-car engines and compressors, which were first mooted in 1912, have been commonplace for the past fifteen years or so as sand castings by the same company, by Jessops and others. The Ford Motor Company has cast its crankshafts for years, more recently by the Shell process, and camshafts and valves as well.

Porosity and control of grain size are being tackled in a variety of ways, as instanced by the cast milling cutters of B.S.A., whose cast steel forging dies are also coming into general use. Vacuum casting, controlled rate of freezing, as by the Parlanti and other methods, and the development of high-duty heat-resisting alloys specially adapted for casting are all playing their part. In the United States cast turbine blades are being used in some aircraft engines.

Where operating temperatures preclude the use of light alloys, iron and nickel-chrome steel castings are used, and are machined all over to obtain consistent thicknesses. Where it is not possible, by reason of the shape, to machine all over, recourse may be had to a composite construction. It is encouraging that in one foundry at least, making static castings, tolerances of ±0·005in on as-cast diameters of 30in or more are within sight of achievement. Further development is urgently needed to enable castings to be produced to the desired thickness without machining. It is a sobering thought that this will only bring us to the stage reached by the ancient Greeks, who were able to cast, by the lost-wax process, bronze statues, one of which was 6ft high, weighing only 100 lb and averaging less than 0·100in in thickness. Earlier Egyptian castings were even thinner.

In castings such as those just postulated there is little doubt that the new spheroidal graphite cast iron will play a big part. With up to double the strength of ordinary cast iron, and much greater ductility and greater stiffness, it will help a great deal to keep material weight down.

There has during the past few years been a tendency to replace cast structures by weldments. Cases have been made out showing appreciable savings in weight and reduced cost due to no pattern being required. These are perfectly true when comparing steel with cast iron, and when considering one-offs, but Fig. 10 shows that cast steel structural members are staging a comeback, in this case in a marine application, and where even quite small quantities are required the cost of the pattern is very soon paid for by the saving in time in cutting out the steel plate and jigging and welding it up and inspecting the welds.

Where shapes are difficult to machine, as in nozzle guide vanes shown in Fig. 10, the most expensive casting method—lost wax investment casting, can be justified. These components are cast to size on the aerofoil and the platform. The small size of the cored holes should be noticed, and in passing it may be mentioned that these are not by any means the longest cores of their size which are being produced.

Bidding fair to produce castings of comparable accuracy is the shell process. As this requires a metal pattern its use cannot always be justified, and there is a limitation imposed, too, by the complexity of the casting. Where profiles can be left as-cast which previously had to be milled, however, great savings both in metal and machining time are possible. Fig. 11 shows cross-sections of a casting produced originally in sand and weighing 107 lb as cast, 11¼ lb finish machined. The first economy was to have the rough machining done by the foundry, since this put a higher value on the scrap than when it was returned from the customer. The final version, by shell moulding, weighs 38 lb, saves nearly £14 worth of material and much machining.

A modern casting development which should help to reduce the cost of bar, forgings and sheet is the continuous casting of billets. By avoiding piping and the other defects of ingots an economy of about 30 per cent is claimed, plus the elimination of ingot moulds.

Fabrication.—Fabricated sheet metal parts occupy an important place in the aircraft gas turbine engine for flame tubes, discharge nozzles, air casings, exhaust units, and jet pipes. Material utilisations as high as 56 per cent are obtained with these components, and they play a big part in the low specific weight of the gas turbine engine.

These components, and the flame tubes in particular, are interesting as representing an incursion into new fields of accuracy in sheet metal parts of their size. The flame tube is made from light-gauge Nimonic sheet, and since the efficiency of combustion and the life of the flame tube itself depend upon the accurate guiding and metering of a stream of air flowing through it at about 20 tons per hour, along carefully predetermined paths, it must be made extremely accurately. Since it is required in not very large quantities as compared with what is usual in the precision sheet metal field, and since the material is extremely difficult to form, requiring several anneals and draws in easy stages for many of the components, it has presented new problems of tooling and manufacture.

The pressings must be free from internal stress, the welds must be of the first quality, and all free edges, as at joints and round the holes, must be carefully radiused and polished. The composite construction, too, entails great

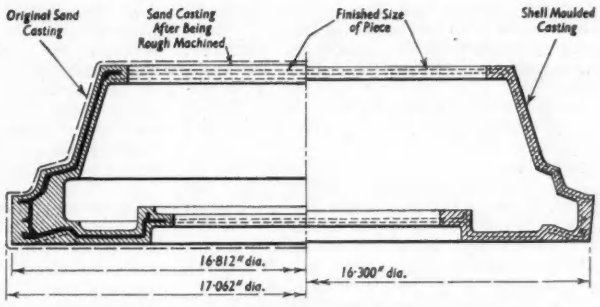


Fig. 11—Comparison of Components when Cast in Sand and when Shell Moulded

accuracy of trimming and locating to ensure that joints fit properly and that the overall tolerances on the assembly shall be met. Wherever possible, in order to improve material utilisation and to reduce the number of tools required, cylindrical components are made by wrapping sheet, welding and sizing.

The subdivision of the costs of material and the different manufacturing operations is rather revealing, as shown in Table II.

TABLE II—*Breakdown of Flame Tube Manufacture*

	Per cent of total cost
1. Raw material	45·5
2. Pressing, forming and shaping	6·7
3. Deburring, radiusing and flash removal	14·2
4. Preparation for welding, i.e. cleaning, jigging and tacking	9·0
5. Welding and brazing	8·3
6. Machining	12·0
7. Miscellaneous handwork, &c.	4·3
Total cost	100·0

The small part played by pressing and forming, and the relative importance of machining, locating, welding and finishing are particularly noteworthy. This analysis is useful as indicating the directions in which efforts should be directed to reduce costs. One thing is immediately apparent : the cost of multiplicity of constituent components as affecting machining, locating and welding. This is in fact the biggest drawback of fabricated construction, and due account needs also to be taken of the cost of tooling, which will be roughly proportional to the number of constituent components.

As normally practised, the multiple sets of tools required for pressing Nimonic components can become an expensive item. In this case expense means not only increased cost per component, but also greatly reduced flexibility and long delays in starting production or in introducing modifications. A considerable effort is being made therefore to reduce the number of tools required by work along a number of lines. One process, known as Dyzacking, is able, by using a proportion of skill along with the necessary tools, to start production of components for a small fraction of the tool cost and several weeks ahead of the normal method. It is still uncertain to what extent this method will be able to compete with the fully tooled method for really large quantities, but for orders of the appropriate size and for a quick getaway it represents a considerable step in the right direction.

Several other methods are being developed, aiming at similar flexibility of output and more universal equipment, so that tooling costs will fall and speed of introduction rise.

Where a complex casting is replaced by a composite fabrication there will in general be an increase in cost, owing to the amount of tooling, accurate trimming, machining and handwork to control and correct welding distortion. In

special cases, however, fabrication may be cheaper than a cast construction.

This is perhaps the place to mention the latest competitor of sheet metal—the plastic laminate. Reinforced with glass or other substance, plastics are providing a serious threat to steel for motor-car bodies, and weight savings of up to 45 per cent in body panels and hard tops are being obtained. With some of the latest reinforcing materials (not glass) costs 15 per cent lower than those of orthodox steel parts are claimed.

This same company again has achieved important weight and cost savings with its Marston Flexelite fuel tanks for aircraft. Made from nylon material of handkerchief thickness, impregnated with hycar, these tanks are crash-proof, and after allowing for the additional structure to contain them, they weigh up to 33 per cent less and cost up to 22 per cent less than metal tanks.

Manufacturing Efficiency.—It goes without saying that efficient shop management and planning play a big part in the ultimate cost of an article, but it is perhaps not generally realised how great in fact can be this influence, and how relatively easy it should be to effect really big improvements to the benefit of all of us.

Fig. 12 shows, on a comparative basis, the costs of a number of components, produced by similar methods and at comparable rates by different firms. This information has been obtained from a number of sources in a variety of industries, and amongst the components are machined parts, forgings, precision forgings and castings, pressings and fabrications.

Great care has been taken to ensure the accuracy and comparativeness of the figures. They take no account of capital expenditure on plant and equipment nor of the cost of tooling

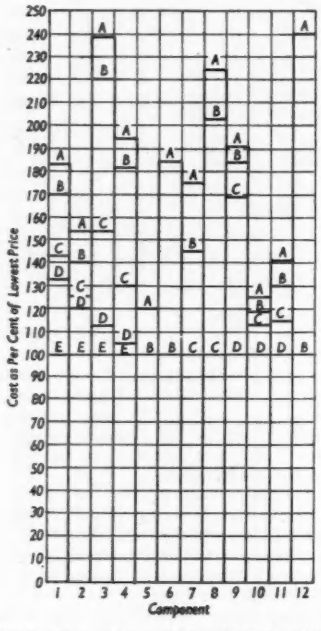


Fig. 12—Comparison of Manufacturing Costs

for the particular components, so that they are in fact a good measure of the production efficiency of the firms concerned. Care has been taken to ensure that the figures are those which apply after initial teething troubles have been overcome and that they hold for comparable quantities.

Through the co-operation of some of those concerned it has been possible to discover a few of the factors responsible. In nearly every case there has been an acceptance of the existing state of affairs as unavoidable, while just plain bad costing has been the next common factor. A great value of the investigations has been the discovery of differing detail practices which have had a considerable influence upon overall material costs and labour times.

Amongst these differences were found in one case a material utilisation of 41 per cent, as compared with 55 per cent in the best case, and accounting for £4 in the cost of a £20 component; in another, a rejection rate double that of the best case, due to the unexpected effect of an "economy" measure; in another, an excessive amount of corrective work which was eliminated by a simple change of method; in yet another, excessive scrap due to inefficient inspection. Differences in incentive methods, and in such elementals as effective shop loading, have had a big influence upon manufacturing times, so much so that differences of 100 per cent have been seen as applying to identical components made by identical methods. It is perhaps not without significance that the best results have in some cases been obtained where there has been least expenditure on tooling.

One overriding difference which is apparent between the better and the more costly concerns is in the outlook of the personnel involved. Those producing the best results have in common a simple, direct and confident approach to the job. This has led to a questioning of the methods and results achieved at each stage, and a refusal to accept the obvious until it has been checked and confirmed. By this means it has been found relatively easy to avoid or eliminate inefficiencies which have had a big bearing on the cost of the component.

Reclamation and Scrap.—With three-quarters or more of the original ingot metal being discarded as croppings or mill loss or machinings or spoilt work there is a fruitful field for recovery. This scrap metal, plus that which is collected as salvage now bulks largely in our overall metals economy. For instance, up to 30 per cent of our tin, 35 per cent of our copper, and 40 per cent of our lead comes from scrap. An appreciable portion of this reconverted scrap comes from salvage, which is becoming increasingly important. Many thousands of tons of aluminium in the form of milk bottle tops, chocolate wrappings, and so on, become waste every year. Collections are made from municipal authorities, and up to 4 tons of ferrous scrap per 1000 of population is gathered in. In addition, about half a million tons of ferrous scrap is imported every year.

In the case of alloys their cost ensures a more careful and rapid return of waste. That occurring in the cogging or rolling mill and the foundry, for example, finds its way back to the furnace pretty quickly. Careful segregation eases the problem of re-melting into the desired alloys, but nevertheless a good deal of work has had to be carried out and much care is necessary to ensure consistency and accuracy of the alloys produced. This is even more difficult with machinings, where cutting oils, dirt and foreign matter may have been introduced.

It is especially noteworthy then to see that it has been established recently that machining scrap of high alloy heat-resisting steels can be reclaimed most economically and even the highly critical Nimonic alloys can now be reproduced safely from their machining scrap. This is indeed an achievement, since the slightest trace of adulterant such as lead can completely ruin a melt. Even if this reclamation were uneconomical financially, it could in time of emergency become absolutely vital. Scrap recovery of this kind has been going on for a long time.

One of the big advantages of the discovery of the casting process, in the Bronze Age, was that tools and weapons which had broken or worn could be recast as good as new, whereas earlier hand forgings could not be reclaimed.

Repair and Maintenance.—Because of their inherently high duty, aircraft engines are usually given short overhaul lives when they are first introduced into service. At the expiry of the specified time, which during the war was 300 to 400 hours for piston engines, the engines are withdrawn for a complete overhaul, which restores them to their full original effectiveness and reliability, for a fraction of their prime cost. It is the constant aim to increase the overhaul life and to reduce the cost of parts needing replacement. In the case of the "Avon" Mark I engine the results have been most gratifying for such an early stage of development, and Fig. 13 shows the small number of parts needing replacement after 800 hours of service. During the war, despite the heavy losses in combat, the overall value of the original effort put into building "Merlin" engines, as measured by the total engine flying hours, was doubled by repair.

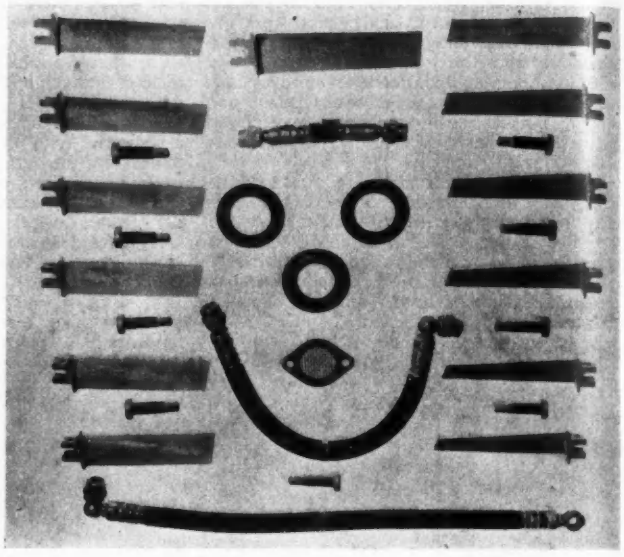


Fig. 13—"Avon" Engine Parts Needing Replacement After 800 Hours

Safety on the Railways

THE third Cantor Lecture on "Safety in Transport" was presented before the Royal Society of Arts on March 8th by Lieut.-Colonel G. R. S. Wilson, the Chief Inspecting Officer of Railways, Ministry of Transport and Civil Aviation. Colonel Wilson's lecture dealt with safety on the railways, and in introducing the subject he pointed out that in the seven post-war years, 1946–52, in this country there was only one passenger fatality for every 35,000,000 passenger journeys, or for every 544 million passenger miles. Despite this, no one, least of all the railways themselves, would say that this record could not and should not be improved. After then giving some particulars of the constitution and work of the railway inspectorate and train accident investigation, Colonel Wilson dealt with signalling, railway brakes, train control, derailments, &c., in some detail. In his concluding remarks the lecturer pointed out that no matter how good the organisation might be, the maintenance of the wide variety of railway equipment depended ultimately upon the staff, the skill and knowledge of which could never be replaced entirely by technical safeguards. Looking to the future, Colonel Wilson said that it was difficult to foresee any startling innovations in the way of technical safety equipment on railways. At its present stage of development radar had no application to prevent railway collisions, and radio communication was of doubtful value to the safety of train operation, although it had been found useful in some kinds of railway control work.

American Engineering News

(By Our American Correspondent)

Extrusion of Non-Uniform Sections

While until very recently extrusion has been a process for producing predetermined metallic shapes in straight lengths of uniform section, it is now being developed further to allow non-uniform sections to be obtained. Much of this development work in America is being done by the Loewy Construction Company, of New York City, under contracts of the U.S. Air Force, and the following notes relate to results obtained by that firm. Stepped extrusions are already being produced in America in a rudimentary fashion on existing presses, using a die design as shown in Fig. 1. A pressing stem extrudes the billet through the die orifice and over the mandrel in the manner of a normal

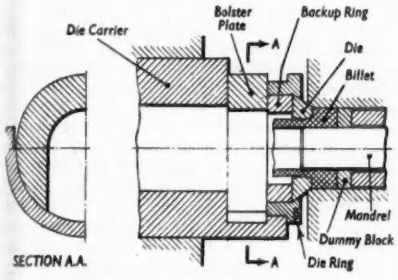


Fig. 1—Step Extrusion Die

direct extrusion. At a given point in the stroke, the extrusion is stopped, and a bolster plate of horse-shoe shape is withdrawn, permitting the removal of the split die. A new die is then inserted, the bolster plate is replaced, and the extrusion is permitted to proceed, thereby producing the "step" extrusion. There are, however, various obstacles to the development of this system on a production basis. The primary objection is the time consumed in interrupting the cycle and in changing dies. In many cases, an even greater objection is the necessity for withdrawing the billet and reheating it in the furnace to regain the plasticity necessary for extrusion. While some of the non-ferrous metals have been "step-extruded" successfully without the necessity of a reheat, a step extrusion

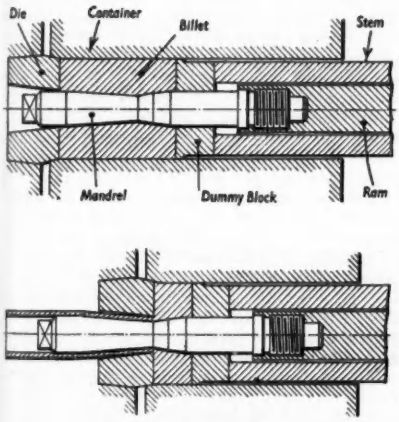


Fig. 2—Die for Constant I.D. Tapering O.D. Section

by the above method has been found impossible in the case of the ferrous alloys. As the need developed for a more completely automatic system of step extrusion, a method was devised by the company in which the dies could be changed automatically with a minimum of cycle interruption. This system has been incorporated in the design of the 20,000-ton extrusion press, which is now under construction for the U.S. Air Force.

With the installation of a 12,000-ton extrusion press at the Curtiss-Wright Corporation a radically new method for the fabrication of propeller blades will be put into production. Experiments conducted by that company had explored the possibility of fabricating a hollow blade propeller with integral shank by the extrusion process. The tests were conducted on a 5500-ton extrusion press at the U.S. Air Force pilot plant in Adrian, Michigan, where a 10ft propeller blade was extruded from a 320 lb alloy steel billet. The extruded blade had excellent physical properties, smooth finish and required only a minimum of subsequent machining. It is expected that the 12,000-ton press will accentuate these advantages, mainly in the

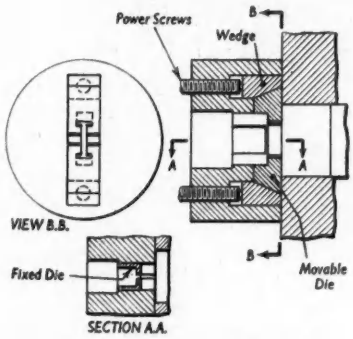


Fig. 3—Die for Tapered I-Section

ability to extrude heavier sections and at higher extrusion reduction ratios.

In America it is now felt that some unusually significant developments in extrusion technique will be forthcoming when exploring the possibilities of combined forging and extrusion on a heavy press. In such a scheme, the ram and stem could be utilised in conjunction with a closed die cavity to form a predetermined forged shape, after which the extrusion could proceed past an extrusion die in the normal manner. An extension of this principle would incorporate auxiliary cylinders on the press to actuate the two halves of a closed die cavity to forge the more intricate shapes, after which the die cavities could be withdrawn and the extrusion die carrier advanced to permit either direct or inverted extrusion to complete the cycle. Some interesting ideas have been advanced recently to produce extruded sections varying in the longitudinal direction, such as the scheme to produce a section of constant i.d. and with a tapering o.d., which is shown in Fig. 2. In this system, a conical mandrel is used, which, at the beginning of the extrusion, is positioned in the die so that the billet is extruded over the maximum o.d. of the mandrel taper. This forms the minimum wall. As the extrusion proceeds, the mandrel advances to the left and a wall of

Fig. 4—Tapered I-Section

increasing thickness is extruded. As the extrusion passes over the large end of the mandrel, a constant i.d. is produced, but because of the varying wall thickness, the o.d. of the extrusion must be increased.

Perhaps the most radical departure from conventional extrusion practice is embodied in the design shown in Fig. 3. This scheme utilises split dies that can be moved laterally during the course of the extrusion to produce a longitudinally tapered section. The diagram illustrates the arrangement at the beginning of the cycle. The vertical spacing of the split dies is controlled by the power screws acting on the dies through the intermediate wedges. The motion of the power screws, and hence the dies, may be controlled by various means. The fixed die is rigidly attached to the die carrier and provides a back-up surface to prevent extrusion of metal past the gap opened by the moving split dies. In the illustration shown, the dies are shaped to produce a tapered "I" section whose final shape is as shown in Fig. 4. A modification of this scheme may be used to produce a tapered "T" section, employing three movable die segments with three fixed back-up dies. While these designs are still in the exploratory stage, it is felt that the very large extrusion presses now being designed and constructed within the Heavy Press Programme of the U.S. Air Force will offer an exceptional opportunity of putting them into operation. In this manner much knowledge and experience should be obtained in the technique of extruding non-uniform sections.

Proposed Conversion of "Liberty" Dry-Cargo Ships

A considerable number of the man "Liberty" dry-cargo vessels, which were built in the United States during the last war, is at present laid up in American waters and is known as the "reserve fleet." One of the main reasons for these ships being considered unsuitable for anything but emergency employment is their slow service speed of 11 knots. An interesting report has now been submitted to the Senate Sub-committee on Maritime Subsidies by a firm of naval architects and marine engineers outlining a method of increasing the speed as well as modernising the hull construction of the 1500 "Liberty" ships in the American laid-up merchant fleet.

In the United States to-day, 18 knots is considered the desirable minimum sea speed for a dry-cargo vessel. Upon examining the form and lines of the "Liberty" ships, it was determined that the 'midship and after body form was suitable for higher speed. The analysis also indicated that the modification to the vessel to attain a sea speed of 18 knots could be confined to the forward one-third length of the ship. This modification would consist of fining the lines, in way of No. 1 and No. 2 holds, and installing a new bow which would increase the length of the ship by 34ft. In order to confirm the opinion that such a modified ship would be capable of performing at 18 knots, a set of revised ship lines was prepared and a model was built and tested in the Experimental Towing Tank at the Stevens Institute of Technology in Hoboken, New Jersey. These model tests indicated that a ship speed of 18 knots, at an average load draft of 25ft, would require 5500 effective horsepower, equivalent to about 6850 s.h.p. for an 18-knot trial speed, allowing about 2 per cent for appendages and assuming an estimated propulsive efficiency of 82 per cent. Again, this was considered equivalent to 8500 normal s.h.p. for a sea speed of 18 knots, making the usual addition for sea margin in accordance with the custom of the U.S. Maritime Administration. It is of interest to note that if this proposed new power plant is put into the present "Liberty" ship, it will not be possible to attain a sea speed of more than about 15 knots, whereas with the modified hull, a sea speed of 18 knots can be attained.

The proposed hull alterations start at the bilge, at the after end of No. 2 hold, and the shell removals extend gradually forward and upward until the entire shell plating from flat of bottom to deck is removed in way of No. 1 hold. The portion of the vessel immediately forward of the forepeak bulkhead is entirely removed. The decks, deep tank top, tank top, as well as flat of outer bottom are retained and modified and the girder and pillar structures and hatches are retained in their present state. At the after end, the existing stern frame, rudder, steering gear and some shell plating and frames are removed and replaced by a design suitable for the increased speed and power. It should be noted that the shell plating, longitudinal girders, decks, &c., amidships are not changed, and that the increase in ship length has been compensated for by a reduction in the maximum draft so that the strength of the longer ship will be at least equal to that of the present design and will meet the requirements of the American Bureau of Shipping.

In order to provide machinery capable of developing 8500 normal s.h.p., it will be necessary to replace the existing main propelling machinery, shafting and propeller. It has been estimated that a number of "Liberty" ships could be modernised in American yards at an approximate cost of 2,200,000 dollars

each, which is probably about one-half the present cost of a new ship to carry the same cargo at the same speed and with equivalent cargo-handling facilities. This cost is exclusive of the present value of the ship, which is about 350,000 dollars on the American market and about 650,000 dollars on the European market. The following table compares the characteristics of the existing " Liberty " ship with those of the proposed modernised vessel.

	Existing ship	Modernised ship
Length between perpendiculars ...	416ft	450ft
Beam moulded	56ft 10in	56ft 10in
Depth to upper deck amidships ...	37ft 4in	37ft 4in
Draft moulded	27ft 6in	26ft 6in
Displacement, tons	14,250	13,350
Total deadweight, tons	10,800	9,415
Cargo capacity, cubic feet	500,000	506,000
Cargo stowage factor, cubic feet per ton	52	63
Sea speed, knots	11	18
Horsepower	2,500 i.h.p.	8,500 s.h.p.

The modernised " Liberty " ship would not have the same useful life as a new ship. The average age of the 1500 ships which are now in the laid-up fleet is ten years. However, the average service age, due to the fact that the ships have not been in use continuously and are laid up in fresh or brackish water, and because preservation methods have been used, is probably seven years. It is also believed that a few hundred of the best ships in the laid-up fleet would have an average service age of only about five years. Therefore, the useful life of the modernised " Liberty " ship would be thirteen to fifteen years, as compared with twenty years for a new ship. In any case, it has been considered economically sound to attach more significance to the useful life of a vessel as a defence or military component than as a commercial cargo vessel, and it has been assumed that the principal interest in the proposed conversion of these vessels is in terms of their military value in times of national emergency.

A Development Plan for the Upper Colorado River Basin

The U.S. Secretary of the Interior recently submitted to the President his recommendation that the Colorado River storage project be submitted to Congress for approval. The storage plan is a bold scheme, conceived by the Bureau of Reclamation in co-operation with the five States of the upper Colorado River basin, to enable them to utilise their apportionment of Colorado River water. It anticipates the irrigation of 380,000 acres of land, the consumptive use of water for industrial and municipal purposes, and the generation of large blocks of hydro-electric power in the States of Wyoming, Utah, Colorado, New Mexico, and Arizona.

The initial recommended phases of the project, which includes three storage dams and reservoirs and thirteen participating irrigation projects, are anticipated to cost 1,134,643,000 dollars. This construction work, although proposed for authorisation at one time, would be staggered over a considerable number of years. The report anticipates that the cost of each unit will be repaid to the U.S. Treasury within a fifty-year period after the unit is completed and in operation. This repayment would include interest on the unamortised balance of the power investment, including that which accumulates during the period of construction. The funds used for irrigation phases of the project are reimbursable but are interest free. To-day, the upper basin States have an urgent need for a considerable amount of reservoir storage space in order to ensure the delivery to the Lower Colorado River basin of 75,000,000 acre-feet of water in any ten consecutive years, as contemplated by the Colorado River Compact. This storage space will enable the upper basin States to conserve flood waters in years of heavy precipitation for use during the inevitable years of drought. To meet this situation the plan calls for a total active reservoir storage space of 37,530,000 acre-feet. After 200 years it is estimated that sediment encroachment will have reduced this active space to approximately 26,000,000 acre-feet. The planned power installation amounts to 1622MW. Revenue from the sale of this energy would repay the entire Federal investment allocated to power as well as a major portion of the cost of the irrigation development. The initial development as recommended for authorisation at this time includes three of ten possible large storage dams and reservoirs and thirteen participating water development and utilisation schemes.

The largest single element in this plan is the Glen Canyon dam and reservoir situated approximately 13 miles upstream on the Colorado River from Lee's Ferry, which is the dividing point between the upper and lower basins. It will be the final regulating and storage reservoir in the upper basin and will be a 26,000,000 acre-feet capacity reservoir behind a dam extending to a height of 580ft above the river bed. The Glen Canyon power station will have an installed capacity of 800MW and the entire scheme is estimated to cost 421,300,000 dollars. Also recommended for authorisation at this time is the Echo Park dam on the Green River just below its confluence with the Yampa, in North-Eastern Utah. This dam will be 525ft high, storing 6,460,000 acre-feet of water and having a 200MW installed power capacity. It is expected to cost 176,400,000 dollars.

Both the Echo Park dam and the Split Mountain dam and their respective reservoirs are situated within the Dinosaur National Monument, one of the national parks of the United States. This had caused considerable public opposition to the construction of these dams and led the Secretary of the Interior to conduct a special investigation of the case. He arranged for the Under-Secretary of the Interior, in company with the Commissioner of the Bureau of Reclamation and the Director of the National Park Service, to visit the sites of the proposed dams and also to inspect a considerable portion of the Dinosaur National Monument and other portions of the upper Colorado River area, where alternative dam sites had been proposed. According to a report issued by the Under-Secretary, " the opposition to the two dams in question arises from persons and organisations interested in the national parks and their desire to preserve the Dinosaur National Monument in its present natural state. The Echo Park dam, in particular, will create a large reservoir within this monument and will certainly alter its appearance and existing conditions. It is a matter of personal opinion as to the extent of harm that may be created by this reservoir. My own feeling is that the alteration will be substantial, and if conflicting interests did not exist, I would prefer to see the monument remain in its natural state. However, I do feel that if the dam is built the beauty of the park will by no means be destroyed and it will remain an area of great attraction to many people. It should be noted that neither of these proposed reservoirs will inundate any portion of the quarry where the dinosaur skeletons have been found." The report continues to state that other dam sites and also the possibility of increasing the height of the proposed Glen Canyon dam had been considered. Any of the alternatives, however, show a net loss from evaporation of not less than 100,000 to 200,000 acre-feet a year. It was felt that in an area where water is so precious this is a matter of very serious consequence, particularly as there would also be a substantial loss of electric generating capacity in any of the alternative sites ; an important factor in the economic feasibility of the scheme. In conclusion, the report states : " I share the concern of those who would preserve the beauties of the Dinosaur National Monument in their present natural state, but as between a choice of altering this scenery without destroying it in a basin which is and will remain rich in scenery, or the irreplaceable loss of enough water to supply all the needs of a city the size of Denver, I believe the conservation of the water in the interest of the nation is of greatest importance."

Portable Bridges for the U.S. Army

The U.S. Department of Defense has announced that three designs of portable bridges are now in the final stages of development and testing by the Research and Development Laboratories of the U.S. Army Corps of Engineers at Fort Belvoir, Virginia. The necessity for the rapid movement of larger and heavier mechanised equipment used by modern military forces has brought about the development of these bridges with wide roadways, designed for more rapid erection and capable of carrying greater loads. Two of the bridges have been designed for launching by armoured vehicles. The " scissors " bridge is carried on, and launched from, a medium (M-46) tank chassis, while the portable assault bridge is pushed across the gap and controlled by a standard U.S. Army M-47 tank. The third design is an aluminium bridge, which is referred to as the " T6," and which is capable of carrying divisional combat and supply vehicles over a wide range of spans. It can be constructed in various lengths in multiples of 15ft by crane or, in emergencies, by manpower from readily transported components. It is expected to replace the Bailey bridge, which was used extensively during the last war by American Forces.

The " scissors " bridge is 60ft long, has a roadway width of 13ft 6in and can carry loads up to 55 tons. The " scissors " and " T6 " bridges were designed by the Research and Development Laboratories at Fort Belvoir, and a limited number are now being manufactured under contract by private industry. For purposes of transport the " scissors " bridge is folded back in halves on the transporting tank. In launching, a series of hydraulic pistons and cables " scissor " the bridge across the gap, after which the tank releases itself. The tank column then can proceed to cross over it. The assault bridge rests on two very large rubber tyres. It is attached by means of a linkage to the standard military tank. It is manœuvred simply by pushing it with the tank and directing it into position. After the bridge is in position the tank releases it and then crosses when the bridge is fully launched. This bridge is 43ft long, has a 13ft 6in roadway width, and is capable of carrying loads up to 55 tons. It was designed and fabricated by private industry under contract to the U.S. Army Corps of Engineers.

Five years of research and work by the structural design staff of the Corps of Engineers, with the co-operation of private American industry, went into the design, developing and testing of a pilot model of the aluminium bridge. This may be built as a single truss, a double truss, and even a triple truss for spans exceeding 180ft and for 55-ton loads. The truss is a rigid framework, which supports the bridge deck. It has been demonstrated that a 75ft length of this new tactical bridge can be manually erected in forty-five minutes or in about one-third of the time required for the same length of bridge of previous designs. One reason for the brief erection time of the new bridge is its light weight. It is approximately 60 per cent of the weight of a comparable steel bridge. The largest single section of the aluminium bridge, the truss panel, weighs approximately one-half of the same section in steel. It is put together in sections with the floor beam resting on the lower horizontal member of the truss panels. Four deck panels stretch over the floor beams to support the wide roadway. In addition to its relative ease of construction, the bridge is said to have a load-carrying capacity about 50 per cent greater than similar structures used during the last war. As a result, substantially more equipment can be transported across the new bridge at one time. At present, sections of the bridge are transported to the erection site by motor vehicles. It is conceivable, however, that in future the bridge may be dropped in sections from transport aircraft.

FIFTH CONGRESS ON LARGE DAMS.—The fifth Congress of the International Commission on Large Dams, which is affiliated to the World Power Conference, will open at Paris on May 31, 1955, it is announced. The congress will include about a week of technical sessions, followed by a study tour in France and North Africa. The technical programme of the fifth Congress will comprise four " questions," namely, Question No. 16 : design and construction of dams on permeable soils and methods of foundation treatment ; Question No. 17 : economic and safety of different types of concrete dams ; Question No. 18 : settlement of dams due to compressibility of the dam's materials or of the foundation soil, including earthquake problems; Question No. 19 : the relation of cement content of the concrete to performance in practice of (*a*) gravity dams (interior and exterior), (*b*) arch dams, (*c*) buttress dams, and its influence on permeability and frost resistance. Offers of papers within the scope of one or other of these questions are invited by the Secretary of the British National Committee on Large Dams, 201-2, Grand Buildings, Trafalgar Square, London, W.C.2.

Industrial and Labour Notes

Productivity and the Human Factor

Last week, a conference to consider "The Human Factor in Productivity" was held at Buxton and was attended by about 200 representatives of provincial manufacturing firms. It was organised by the British Institute of Management, the Institute of Personnel Management, and the Personnel Management Advisory Service of the Ministry of Labour.

The opening address at the conference was given on Thursday of last week by Mr. Harold Watkinson, Parliamentary Secretary to the Ministry of Labour, who spoke about the Government's desire to assist the strengthening of industrial negotiating machinery. Mr. Watkinson emphasised that he was not advocating any procedure which would in any way dictate wages policy. The Government's place in industrial relations remained unchanged; it was to provide whatever legislation or machinery which might be necessary to help industry to develop its own self-government in determining wages and conditions and in settling disputes. If an industrial dispute could not be settled locally, Mr. Watkinson continued, there should be a recognised procedure for bringing it to the national level. If it could not be settled there by negotiation, it should be referred automatically to some form of arbitration. That, he observed, could be arbitration set up by the industry concerned, and perhaps based on a model constitution drawn up by the Ministry of Labour, or arbitration under the Industrial Courts Act, or by the Industrial Disputes Tribunal. Mr. Watkinson went on to express his belief that it would be realised that strike action and the lock-out were outmoded weapons. But, he said, he believed equally strongly that it should remain the clear right of any union and any employer to have recourse to these most drastic weapons if they felt they had no other means of obtaining justice. The aim must be not to ban strikes and lock-outs, but to make them unnecessary. This could be done, Mr. Watkinson asserted, by having a sound system of arbitration so that justice was both done and seen to be done.

Mr. Watkinson also said that to-day a distinction was made between industrial relations and human relations. It was, he thought, a useful distinction and directed attention to the central problem of industry which was confidence at shop floor level. Despite all the threats of national trouble in industrial relations, this country had gone a very long way in building confidence and good faith between the great representative organisations of employers and workpeople which carried out their task at national level. But, Mr. Watkinson observed, not nearly so much progress had been made in solving the problem at the level of the 50,000 or 60,000 individual undertakings. The hidden results of bad relations in industry, leading to poor team-work and lowered efficiency and output were dangerous. Improved efficiency and output, Mr. Watkinson said, would ensure success in expanding exports and in maintaining a healthy balance of payments position. Provided no abnormal trends developed in world trade, there was no reason, he suggested, why increased pay should not be the reward of increased output or increased efficiency.

Work Study in the Coal Mining Industry

A series of talks on the application of work study to the coal mining industry has recently been given to the Mining Society of King's College, Newcastle upon Tyne. The talks were summed up on Wednesday of last week by Mr. E. H. Browne, director-general of production to the National Coal Board.

Mr. Browne emphasised that the main aim of work study was to make the most effective use of labour, and to provide the essential facts on which management could take day-to-day action and on which long-term decisions could be based. Work study involved an objective analysis of every operation which went to make up a particular job and was not a hit and miss method of appraisal depending on the instinct or whim of an individual. Mr. Browne went on to say that co-operation with the National Union of Mineworkers and with the colliery consultative committee was essential and that their confidence must be gained. Work measurement had been extensively used, particularly in the U.S.A., to provide a basis for agreement of tasks for wage rates and incentive schemes, though its first objective was not to fix wage rates or tasks. Reduced to its simplest terms, the whole basis of work study was no more than critical and, above all, factual analysis of the jobs that were done.

There were two ways, Mr. Browne continued, of training work study engineers for the coal industry. Mining engineers could be given training in work study, or men familiar with work study could be introduced to coal mining. He thought there was some advantage with the latter because there was no doubt that familiarity with the traditional approach tended to obscure the critical faculty. On the other hand, Mr. Browne said, it was important in the early stages to secure the confidence of the mining management, and that might be done most easily by bringing in work study through men who had already proved themselves in the industry and who would command respect wherever they went. He therefore favoured, for underground work, training mining engineers for work study.

Britain's Overseas Trade

The Board of Trade has given the provisional value of United Kingdom exports in February as £201 million. There were only twenty-four working days in February so that the daily rate of exports was about the same as in January. If January and February are considered together, exports of United Kingdom goods were at an average value of £213,400,000 a month, which was 7 per cent below the average in the fourth quarter of last year, but more than 3 per cent above the average for the corresponding months of last year. Imports in January and February averaged £262 million a month, which was 5 per cent below the monthly average for the fourth quarter of last year. With re-exports in February valued at £8,200,000, the excess of imports over total exports in January and February averaged £40,500,000 a month, or 10 per cent more than the average in the preceding quarter.

World Steel Production

A survey made by the British Iron and Steel Federation, and published in its *Monthly Statistical Bulletin*, shows that world steel production last year reached a record total of 230 million tons. This, it is stated, was more than 11 per cent above the 1952 total and nearly twice the 1937–38 average. It is suggested that the large increase reflects the loss of American steel production in 1952 rather than the growth of requirements in 1953. Indeed, it is stated, for the first time since early 1950, signs of over-supply of steel in the world at large began to make their appearance last year, and in a number of countries steel production rates declined in the later months of 1953.

According to the survey, most of the 11 per cent increase in steel output last year was accounted for by bigger American production. In 1952, the strike in the American steel industry depressed output by an estimated 17,000,000 tons and consequently forced consumers to run down their stocks. But once the deficit had been eliminated, by the summer of last year, American steel production rates fell. It was thus an unusual set of circumstances which raised world steel production last year to so high a level as 230 million tons. The survey suggests that an average of the two years 1952 and 1953, which is 219 million tons, may be a better indication of the level of output required to meet current demand. The comment is made in the survey that "an approach to that level during the current year will not be surprising unless there is a sharp recovery of general business activity in the U.S.A." By contrast with American experience, the survey adds, in the countries of the European Coal and Steel Community the decline in demand was severe enough to reduce steel production last year by 5 per cent compared with 1952. It is thought that uncertainty prior to the formation of the common market may have led consumers in those countries to build up their stocks, although it is generally agreed that there was a widespread move to run down stocks later in the year, thus affecting production.

About steel production prospects, the survey says that world output, on present forecasts, is not expected to rise at the same rate as in the immediate past. Between 1948 and 1953, the world total increased by 77,000,000 tons, but during the next five years it is not expected to grow by much more than 48,000,000 tons in the absence of unforeseen circumstances such as the Korean war.

Wage Negotiations

During the last week or so, the British Employers' Confederation, the nationalised industries, and the economic committee of the Trades Union Congress have signified to the Minister of Labour their willingness to participate in talks concerning the establishment of an impartial body to study the economic implications of wage claims. It will be recalled that such a body was suggested by the Courts of Inquiry which recently investigated the wage disputes in the engineering and shipbuilding industries.

In their reports, the courts expressed the view that some of the issues raised during their inquiries were essentially part of much wider problems affecting the national economy. They, therefore, reached the conclusion that it might be a most valuable contribution to the solution of those wider problems if an authoritative and impartial body was appointed to consider them and the complex and sometimes conflicting arguments which surround them. Such a body, the reports suggested, might "give advice and guidance as to broad policy and possible action."

At the beginning of this week it was stated that the executive council of the Amalgamated Engineering Union was not in favour of the suggestion for the setting up of an "impartial body" made in the report on the engineering wage dispute. The A.E.U. appears to take the view that the recommendation hints at the establishment of a national wages policy, to which it is opposed.

Employment and Unemployment

The Ministry of Labour has estimated that, during January, the working population of Great Britain increased by nearly 20,000, bringing the total to 23,491,000 (15,942,000 men and 7,549,000 women). Of that total 22,283,000 (14,877,000 men and 7,406,000 women) were in civil employment.

In its analysis of the figures relating to civil employment in January, the Ministry states that 3,987,000 were engaged in the basic industries, which showed a net decrease of 1000 compared with the preceding month. In the manufacturing industries, in January, there was a net increase of 23,000 in the number of people employed, which brought the total by the end of the month to 8,955,000. The principal changes in these industries were in the group classified as "engineering, metal goods and precision instruments," in which there was an addition of 8000, bringing the number employed to 2,610,000, and in vehicle manufacturing, where there was an addition of 6000, making the total employed 1,162,000. In other industries and services, the employment changes in January were seasonal ones, the number employed in building and contracting, for example, dropping by 11,000 to 1,390,000.

The latest figures concerning unemployment in Great Britain relate to February 15th, on which date there were 387,303 people registered as out of work, compared with 372,856 on January 11th. The Ministry of Labour has estimated that the February figure represented 1·8 per cent of the total number of employees.

Notes and Memoranda

Rail and Road

SALOON CAR WITH IMPROVED PERFORMANCE.—A new version of the "Conquest" saloon with greater power, more passenger room and improved equipment has been announced by the Daimler Company, Ltd. Production of the standard "Conquest" saloon will continue. Basically the new car is similar to the standard "Conquest" in exterior lines and chassis and engine design. With the same 3in bore and 3½in stroke the engine power has been increased from 75 b.h.p. at 4000 r.p.m. to 100 b.h.p. at 4400 r.p.m. by fitting dual carburetters, a special aluminium cylinder head, high-speed camshaft, larger valves and twin exhaust manifold. Modifications in chassis design include larger diameter propeller shaft, four-star pinion differential and ½in wider brakes, giving 33 per cent increase in braking surface at 184 square inches. Otherwise engine and chassis design and construction remain unchanged and, except for the items listed, parts and assemblies are common to both the "Conquest" and the "Conquest Century" models.

EXPERIMENTS WITH LOW-VISCOSITY OILS.—It is stated by London Transport that the use of engine lubricating oils of lower viscosity than hitherto is now achieving an economy in oil fuel consumption of about 6 per cent, which with an annual fuel bill of well over £6,000,000 for the fleet of 8000 buses and coaches, represents a saving at the rate of £390,000 a year. Research into the matter dates from the hard winter of 1947, when London Transport established that an oil of SA.E. 20W viscosity, initially employed as an aid to easier starting from cold, could also be used as a summer grade of lubricant. Carefully controlled tests disclosed no ill effects on engine life, no loss of performance and no appreciable increase in the consumption of lubricating oil, while the oil fuel consumption dropped by 3½ per cent. This winter an oil of still lower viscosity, S.A.E. 10W, has been adopted and has resulted in further reducing fuel consumption by about 2½ per cent. This oil is at present only being used as a winter grade, but is likely to be standardised for use throughout the year.

Air and Water

ORIENT LINER.—The Orient liner "Orsova," which was built by Vickers-Armstrongs, Ltd., and sailed on her maiden voyage on Wednesday, March 17th, attained a mean speed of slightly more than 26 knots during trials over the Arran course.

MAIDEN VOYAGE.—The "Saxonia," which is the first of three such liners building for the Cunard Steamship Company, Ltd., at the yard of John Brown and Co. (Clydebank), Ltd., is expected to leave Liverpool on September 2nd on her maiden voyage to Quebec and Montreal.

MEETING OF THE COMMUNICATIONS DIVISION OF I.C.A.O.—The fifth session of the Communications Division of the International Civil Aviation Organisation (I.C.A.O.) opened at Montreal on March 9th, to discuss matters concerning the application of telecommunications and radio navigational aids to civil aviation. Among the various subjects being discussed are items on long range navigational aids, secondary radar, methods of improving air to ground communications and the general testing of navigational aids. There is also a review of frequency and fixed telecommunications problems. The U.K. delegation includes representatives from the G.P.O., the Radio Communication and Electronic Engineering Association and International Aeradio Limited, and is led by Mr. J. C. Farmer, Deputy Director of Telecommunications in the Ministry of Transport and Civil Aviation. The meeting is expected to last for five or six weeks.

Miscellanea

DYNAMOMETERS FOR SWITZERLAND.—An "RFA 13" dynamometer, having a capacity of 10,000 b.h.p. at speeds between 125 and 300 r.p.m., and of the latest Froude design, is the first of a number of new dynamometers of up to 15,000 s.h.p. capacity to be installed in the test shops of Messrs. Sulzer Bros., Winterthur.

BOTTLED GAS PLANT.—To satisfy the increased demand for bottled gas the existing plant at the Grangemouth refinery is to be extended and new plant for bottling gas as a liquid will be ready next year to increase present capacity from 7000 to 16,000 tons a year. Four "Hortonspheres" for the storage of liquid butane under pressure have been installed, together with three propane storage vessels.

INSTITUTE OF BRITISH FOUNDRYMEN.—In connection with its fiftieth anniversary celebrations, the Institute of British Foundrymen has organised a "Jubilee competition" for its younger members. The national award in this competition is to be presented to Mr. D. F. Bailey, of Coventry, for a paper entitled "Some Aspects of Shell Moulding Technique." Five other prizes are being awarded for papers submitted by members of the Institute's various branches.

SIR JOHN PARSONS, HONORARY MEMBER OF THE ILLUMINATING ENGINEERING SOCIETY.—The Illuminating Engineering Society has conferred honorary membership upon Sir John Herbert Parsons, who is a past-president of the Society and was the first chairman of its Council. For many years he was surgeon and, later, consulting surgeon at the Royal London Ophthalmic Hospital (Moorfields), as well as ophthalmic surgeon and, subsequently, consultant at University College Hospital, London. He is a Fellow of University College, a Fellow and past-president of the Royal Society of Medicine, a Fellow of the Royal College of Surgeons, and a Fellow of the Illuminating Engineering Society. The certificate of honorary membership was presented to Sir John by the president of the Society, Mr. W. R. Stevens, at a Council meeting on March 9th.

FILM ABOUT MOBILE CRANES.—R. H. Neal and Co., Ltd., Plant House, Ealing, London, W.5, has made a film which shows the manufacture and uses of the mobile cranes made by the firm. The film is in colour and explanation of the manufacture of the cranes, and of the mechanical handling operations which they are shown carrying out, are given in a commentary.

"CEMENTATION."—The Cementation Company, Bentley, Doncaster, has published a booklet giving examples of the many applications of the process known generally as "cementation," in civil and mining engineering. "Cementation" proper and the allied geotechnical processes have been developed by the company over many years and a list of the works it has carried out is given in the booklet.

CAREERS IN CHEMICAL AND MINING ENGINEERING.—The Ministry of Labour has prepared a revised edition of booklet No. 19 in its *Careers for Men and Women* series. It contains a great deal of information which will be valuable to those who require guidance on careers in chemical engineering, mining engineering, gas engineering and oil prospecting and production. The booklet is published by H.M. Stationery Office at 1s. 6d.

EXHIBITION OF MODELS.—The Northern Association of Model Engineers will hold its sixth exhibition from Friday to Sunday, March 26th to 28th, in the Corn and Produce Exchange, Hanging Ditch, Manchester, from 11 a.m. to 9 p.m. each day. The exhibits will include steam locomotives, boats, aircraft and other items submitted by model makers in all parts of the country. The honorary secretary of the Association is Mr. Ralph Woods, 214, Middleton Road, Hopwood, Heywood, Lancs.

INDUSTRIAL FILMS—Two films made for Broom and Wade, Ltd., of High Wycombe, were shown for the first time in London last week. One of these films deals with the firm's works and graphically describes the plant and methods used in manufacturing the many kinds of air compressors and pneumatic tools produced at High Wycombe. The second film opens with a brief account of the firm's origin and then deals with the many applications of "Broomwade" equipment in various parts of the world.

BLAST-FURNACE AT SCUNTHORPE.—A new blast-furnace, with a hearth diameter of 27ft, was recently blown in at the Appleby-Frodingham works at Scunthorpe, of the United Steel Companies, Ltd. The furnace, which will make 6000 tons of iron a week, is part of the expansion programme being carried out at the Appleby-Frodingham works under the title "Operation Seraphim." Another new furnace, with a hearth diameter of 28ft 6in, is under construction. The extent of these new works was described in the annual review of progress in the British iron and steel industry which appeared in our issue of January 8th.

ALUMINIUM AND STEEL.—The United Nations Economic Commission for Europe has issued a document entitled "Competition Between Aluminium and Steel," which has been prepared by its secretariat. It is stated to be the first of a series of studies on metals and materials competitive with steel. The principal conclusion set out in the present document is that, from the viewpoint of total consumption, competition between iron and steel and aluminium is still and will remain on a small scale. The most important area of competition, it is stated, is with thin, flat products, where aluminium is competing with steel to the extent of about 3 per cent of the world output of thin, flat products.

HIGH-LIFT MECHANICAL LOADER.—A mechanical loader with a clearance of 14ft 6in under the lip of the bucket when tipped is now being made by E. Boydell and Co., Ltd., of Old Trafford, Manchester. The new machine, which retains a safe working stability even with full load at maximum height and forward reach, is intended primarily for feeding and loading elevated hoppers. It is available with either a standard ¾ cubic yard bucket or with a coke type 1 cubic yard full-width scoop. We are informed that during a recent test under actual working conditions the loader negotiated a 1 in 7 ramp to load 15 tons of sand in fifteen minutes into a bin over 11ft in height from the top of the ramp.

"UNCOMMON CLAY."—We have received from the Morgan Crucible Company, Ltd., a book entitled *Uncommon Clay*, which describes the new works of the Morgan Refractories Group at Neston, and some of the many products it manufactures. The book first traces briefly the history and growth of the parent company and the creation of Morgan Refractories, Ltd., which led eventually to the laying down of the new Neston works for the production of the "M.R." aluminous refractories, low heat storage refractories and castables, cements and mouldables. A series of excellent photographs shows some of the processes and products of the works and lists are given of their applications in industry.

RADIO INDUSTRY COUNCIL PREMIUMS FOR TECHNICAL WRITING.—Presentations of the Radio Industry Council's premiums for technical writing for the year 1953 were made at a luncheon in London on Thursday, March 11th, by the chairman of the council, Mr. G. Darnley-Smith. The premiums, each of 25 guineas, accompanied by a certificate, were awarded as follows:—To Mr. G. G. Gouriet for his article "Spectrum Equalisation" (*Wireless Engineer*, May, 1953); to Mr. A. W. Keen for his article "Triode Transformation Groups" (*Wireless Engineer*, October, 1953); to Messrs. A. H. Beck and A. D. Brisbane for their article "A Cylindrical Magnetron Ionisation Gauge" (*Vacuum*, April, 1952); to Mr. H. M. Davis and Miss Joyce E. Seaborn for their article "A Linear Sweep Cathode-Ray Polarograph" (*Electronic Engineering*, August, 1953); to Mr. J. R. Pollard for his article "Selective Calling for Radio Telephone Systems" (*Electronic Engineering*, December, 1953); and to Dr. D. McMullan for his article "The Scanning Electron Microscope and the Electron-Optical Examination of Surfaces" (*Electronic Engineering*, February, 1953); the latter award was not presented at the luncheon owing to the absence of the author in Canada. We may recall that the purpose of the Radio Industry Council's premiums is "to encourage the writing and publication in the Press of articles reporting technical progress and development of radio television and electronics in Great Britain."

TESTS ON SURFACE DRESSING BINDER DISTRIBUTORS IN SCOTLAND.—We are informed by the Department of Scientific and Industrial Research that facilities have now been provided at the Scottish Branch of the Road Research Laboratory, Thorntonhall, Glasgow, for checking sprayers where tests are now carried out for a fee. The method of testing used is that developed by the Association of Road Surface Dressing Contractors. Fourteen machines were tested at the Laboratory during the spring of 1953. Only one sprayer on its initial test gave a distribution which complied with the standard laid down by British Standard No. 1707. The other thirteen sprayers required minor adjustments, such as realignment of the jets or the replacement of worn or unsatisfactory jets before the best results were obtained. The results indicate, it is stated, that if sprayers are to be maintained at a satisfactory standard they should all be subjected from time to time to a test of this kind. The Road Research Laboratory strongly recommends that all owners of sprayers should build testing pits in their own depots. Their machines could then be tested regularly as part of routine maintenance.

Personal and Business

MR. J. V. SPENLOVE BROWN has been appointed technical sales manager of Visual Planning Systems, Ltd., Alperton, Middlesex.

FLIGHT REFUELLING, Ltd., Blandford, Dorset, states that Mr. P. R. Allison, its senior experimental engineer, has been appointed service manager.

MR. G. A. HANNAH, managing director of Pegson, Ltd., has been appointed a director of the parent company, Mellor Bromley and Co., Ltd.

BIRLEC, Ltd., states that its northern area organisation is to be moved, on March 25th, to 317, Glossop Road, Sheffield, 10 (telephone, Sheffield 63258).

MR. O. G. Voss has been appointed assistant managing director of International Harvester Company of Great Britain, Ltd., 259, City Road, London, E.C.1.

THE SKEFKO BALL BEARING COMPANY, Ltd., states that Mr. E. Y. Caswell, district manager at Bristol, has been appointed sales manager at the headquarters at Luton.

MATTHEW HALL AND CO., Ltd., Dorset Square, London, N.W.1, states that Mr. B. Rostron Baden has been appointed an alternate director of Matthew Hall (Pty.), Ltd.

MR. JAMES HODGE, senior consultant of Power Jets (Research and Development), Ltd., has left for Columbia University, New York, where he is to act as visiting professor in gas turbines.

THE SOCIETY OF MOTOR MANUFACTURERS AND TRADERS states that Mr. D. B. Morren has been appointed to act as assistant to Sir William Walsh, K.C.B., the Society's representative in North America.

REGENT OIL COMPANY, Ltd., 117, Park Street, London, W.1, announces the appointment of Mr. J. D. Garst as operations director. Mr. O. H. Fish has been appointed assistant general sales manager.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., announces the appointment of Mr. P. M. Hollingsworth, M.I.E.E., as chief engineer of its power cables division, at 21, Bloomsbury Street, London, W.C.1.

W. T. HENLEY'S TELEGRAPH WORKS COMPANY, Ltd., announces the appointment of Mr. E. H. Nichols as Norwich branch manager, in succession to Mr. J. Newton, who has retired after forty-five years in the company's service.

HOOVER, Ltd., states that, at its forthcoming annual general meeting, Sir Charles Colston will retire from the offices of chairman and managing director, after thirty-five years in the company's service. Mr. J. A. Wykes has been appointed to succeed Sir Charles as managing director.

MR. J. G. MILES has been appointed power systems engineer of Metropolitan-Vickers Electrical Company, Ltd., Trafford Park, Manchester. He succeeds Mr. C. P. Storr, who has been transferred to the Dominions division of Metropolitan-Vickers Electrical Export Company, Ltd.

THE HAWKER SIDDELEY group announces the following appointments in the production department of Gloster Aircraft Company, Ltd.:—Mr. W. W. Downing, works manager; Mr. A. J. Pack, production manager; Mr. C. R. Bromage, assistant production manager; Mr. W. S. Horton, production development engineer, and Mr. D. J. Tombs, jig and tool drawing-office manager.

British Patent Specifications

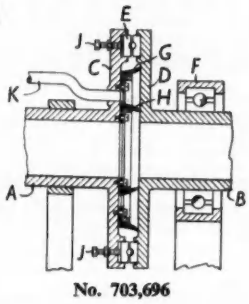
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of the specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

SEALING DEVICES

703,696. November 20, 1950.—SEALING GLANDS, Metropolitan-Vickers Electrical Company, Ltd., St. Paul's Corner, 1–3, St. Paul's Churchyard, London, E.C.4 (*Inventors: Godfrey Burrows and Philip Percy Starling*).

The invention relates to arrangements for effecting sealing, against the ingress of air, between rotatable parts of vacuum equipment. In the drawing the invention is shown applied to the sealing of a rotatable joint between parts of a high vacuum pipeline, the two parts being arranged for relative rotary movement. The meeting ends of the two parts *A* and *B*, are formed with flanges *C* and *D*, which are separated by a bearing that resists the thrust due to atmospheric pressure and may take the form of an annular ball race *E*, the part *A* being stationary and the part *B* being mounted for rotation in a bearing *F*. In the space enclosed between the bearing *E* and the two flanges *C* and *D* are arranged two concentric



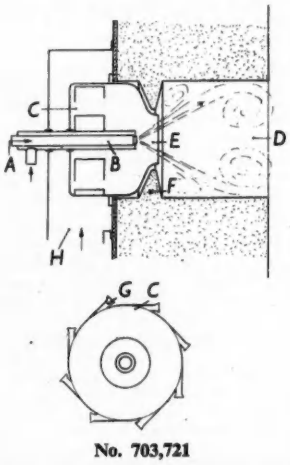
No. 703,696

flexible seals *H* and *G*. These seals are attached to the flange *C* in such manner as to make contact with the other flange *D*, the contact pressure being controlled by providing axial adjustment by means of the screws *J*. In operation the space between the two flexible seals *G* and *H* is connected with the rough vacuum by means of the pipe *K* so that any air leaking past the outer seal *G* will be carried away by the backing pump, while the difference between the pressure in the space between the seals *G* and *H* and that in the interior of the pipeline which forms part of the vacuum system is so small that leakage past the inner seal *H* will be negligible.—*February* 10, 1954.

BURNERS AND SPRAYERS

703,721. July 30, 1951.—APPARATUS FOR BURNING LIQUID FUEL, Naamlooze Vennootschap de Bataafsche Petroleum Maatschappij, 30, Carel van Bylandtlaan, The Hague, The Netherlands.

The invention relates to the improving of the efficiency of combustion of fuels, especially of heavy fuels such as bitumen. Referring to the drawings, fuel is supplied, as indicated by the arrow *A*, to a



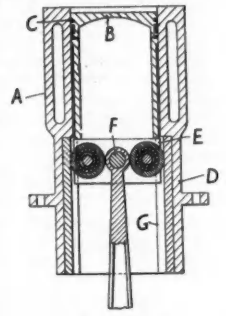
No. 703,721

swirl chamber or pressure atomiser *B*, and issues from it in the form of a hollow cone of spray. Although an atomiser operating exclusively by fuel pressure is to be preferred, it is also possible to use an auxiliary atomising fluid, such as air or steam, provided that the resulting spray of fuel has the form of a hollow cone. The atomiser is situated in a cylindrical air chamber *C*. A combustion chamber *D*, of refractory material coaxial with the air chamber *C*, is connected to the air chamber by means of an orifice *E*, the diameter of which is smaller than that of either chamber. The combustion chamber has at *F* an annular ridge, in which the orifice of the air chamber is accommodated. The axial location of the atomiser in the air chamber is such that the fuel cone enters the combustion chamber near the edge of the orifice. The chamber *C* is provided at its periphery with a number of tangential air entry slots *G* through which air from a casing *H* can enter tangentially. When the apparatus is in operation air is introduced into the air casing *H* at a suitable pressure. Owing to its tangential entry into the air chamber, the air moves with a rotational component of motion towards the orifice *E*, and since the diameter of this orifice is smaller than that of the air chamber, the rotational speed of the air in this orifice is considerably increased. The result is that the fuel cone passing the edge of the orifice *E* meets the air entering the combustion chamber *D* through the orifice, and a very intimate mixing of fuel and air takes place which promotes ignition and combustion in the combustion chamber. —*February* 10, 1954.

POWER TRANSMISSION

703,402. August 21, 1950.—MECHANISMS FOR CONVERTING RECIPROCATING INTO ROTARY MOTION Charles Frederick Byron Powley, 46, Glen Road, Wadebridge, Cornwall.

The invention relates to mechanisms for converting reciprocating motion into rotary motion and vice versa. Referring to the drawing, a cylinder *A* of an internal combustion engine has mounted in it a hollow piston *B*. The cylinder *C* has formed integrally with it a downwardly depending skirt portion *D* of larger bore than the cylinder. The skirt is formed with projecting lugs by means of which the cylinder assembly is secured to the crank case of the engine. The piston has at its lower end a substantially solid portion *E* having a diametrically extending slot of a width sufficient to receive the small end of a piston-rod which is pivotally mounted by a spindle *F* extending across the slot. Rotatably mounted in the slot is a pair of rollers which project slightly from the ends of the slot, each roller bearing against a flat surface formed on the inner surface of a member *G* extending longitudinally of the skirt portion and secured to it by means of bolts. The rollers are supported upon spindles by means of roller bearings. It will be seen that as the piston reciprocates in the cylinder the thrust due to the angular displacement of the piston rod about its pivot is taken by the rollers, thus relieving the piston head of substantially any lateral thrust and thereby considerably reducing wear between the piston head and the cylinder wall. Modified designs are also shown in the specification.—*February* 3, 1954.

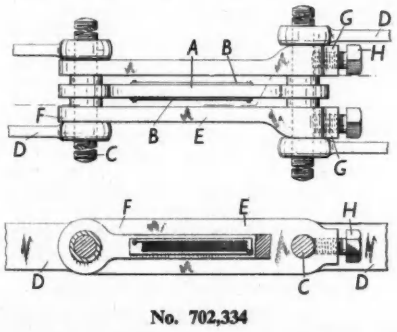


No. 703,402

ELECTRICAL ENGINEERING

702,334. February 7, 1951.—ELECTRIC OVERHEAD LINES, A. Reyrolle and Co., Ltd., Hebburn-on-Tyne (*Inventor: Herbert Loebl*).

The invention relates to the provision of means for enabling overhead conductors to be erected under predetermined mechanical tension. The arrangement shown in the drawing employs a tension element,

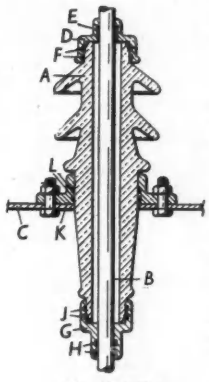


No. 702,334

including a straight bar *A* of suitable metal to which one or more resistance wire strain gauges *B* are stuck. The bar has enlarged ends having holes through which pass a pair of pins *C* which also pass through shackles *D* for connecting the link mechanically in series with the line conductor and insulators. The ends of the pins also extend through a pair of tension relieving links *E*. Each of these has at one end *F* a hole which is a close fit round the adjacent pin and in the other end *G* a slot allowing for some longitudinal play of the pin, and a longitudinal bolt *H* which can be screwed in or out through a threaded hole in the end of the tension relieving link so as to force the pin along the slot a sufficient distance to transfer the tension to the tension relieving elements. The whole of this assembly is connected at a suitable point mechanically in series with the line conductor. In use the tension link is connected in position and a turn-buckle is included at a suitable point between it and the adjacent tower or other support. A resistance measuring device is connected to terminals on the strain gauges, and the turn-buckle is then tightened until a suitable tension is indicated. The resistance measuring equipment can then be removed, leaving the strain gauges in position.—*January* 13, 1954.

702,608.—May 9, 1951.—ELECTRIC INSULATORS, John Edward Cox, 75, Ivanhoe Parade, Ivanhoe, N.21, Melbourne, Australia.

The object of the invention is to provide a simple and reliable joint for high-tension insulators, which can be made liquid or gas tight. The drawing shows the invention applied to a transformer bushing; joints which are gas, water and oil tight have to be made between the porcelain insulator *A* and the conductor *B* of the bushing both outside and inside the transformer tank, the cover of which is indicated at *C*. Also a similar joint has to be made between the insulator *A* and the cover *C*. At the outside of the tank there is a jointing member *D* consisting of a non-ferrous casting formed with internal annular grooves to receive one pair of the yielding rings *E* which make a joint with the conductor *B*, and another pair of rings *F* which make joint with the outside surface of the insulator. A non-ferrous casting *G* is used inside the tank and formed with grooves to receive one pair of yielding rings *H* for making a joint with the conductor and to receive another pair of rings *J* making joint with the outside of the insulator exactly at the top. To make a joint with the tank cover *C* a flanged member *K* is secured by bolts to the cover and has a pair of annular grooves to receive a pair of yielding rings *L* for making a joint with the outside of the insulator. The insulator is shown with the usual sheds. Alternative designs are also shown in the specification.—*January* 20, 1954.

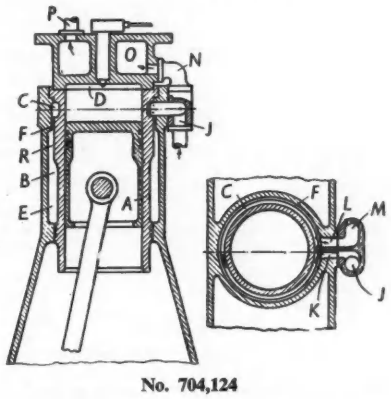


No. 702,608

INTERNAL COMBUSTION ENGINES

704,124. January 28, 1952.—LIQUID COOLING SYSTEMS, Sulzer Frères Société Anonyme, Winterthur, Switzerland.

In the engine shown in the drawings a cylinder liner *A* is surrounded by a cooling chamber *B* which consists of a main cooling space *C* situated near to the combustion chamber *D* and an auxiliary cooling space *E* situated around the lower part of the cylinder liner. The spaces *C* and *E* are connected together



No. 704,124

through a constricted annular gap *F*. Coolant enters through a passage *J* and a conduit *K* in the water jacket. After flowing round the annular cooling space *C* with a velocity of, say, 6ft per second, in the direction of the arrows, the coolant passes out through an outlet conduit *L* in the water jacket *G*

a passage *M*, a connection *N* leading to the cooling space *O* of the cylinder head and then out through a pipe *P*. Only a relatively small amount of coolant circulates from the main cooling space *C* through the gap *F* into the auxiliary cooling space *E*, so that the degree of cooling at the lower part of the cylinder liner is small compared with that effected adjacent to the combustion space. The cylinder liner has a thickened zone *R*, the upper edge of which forms the lower limit of the main cooling space *C*. This thickened zone also bounds the gap *F* and serves to strengthen the cylinder liner. A modification is also described.—*February* 17, 1954.

Catalogues

NEWMAN INDUSTRIES, Ltd., Yate, Bristol.—Machine tool stock list No. 1099.

HIGH DUTY ALLOYS, Ltd., Slough, Bucks.—Booklet entitled "Engineering in Hiduminium."

ALFRED HERBERT, Ltd., Coventry.—Leaflet dealing with "Hypercut" butt-welded lathe tools.

RICHARDSONS, WESTGARTH AND CO., Ltd., Wallsend-on-Tyne.—Booklet entitled "Power for Industry."

HERBERT WIDDOWSON AND SONS, Ltd., Canal Street Works, Nottingham.—Machine tool stock list.

STORDY ENGINEERING, Ltd., Cumbria House, Goldthorn Hill, Wolverhampton.—Catalogue giving details of industrial ovens for the tin printing, varnishing and lacquering of sheets.

BIRLEC, Ltd., Erdington, Birmingham, 24.—Booklets entitled "Carburising Gas," "Shaker Hearth Conveyor Furnaces," "Electric Furnace Brazing," and "Lectromelt Arc Melting Furnaces."

HILGER AND WATTS, Ltd., 98, St. Pancras Way, London, N.W.1.—Booklet describing Hilger spectrographic equipment for metallurgical and general chemical analyses. Also leaflets C.H. 313/4, "Schwarz Thermopiles," C.H. 334/2, "Hilger Equipment for Raman Spectrography," and C.H. 328/3, "Controlled Source Units for Spectroscopy."

Launches and Trial Trips

ANTERIORITY, oil tanker; built by the Goole Shipbuilding and Repairing Company, Ltd., for F. T. Everard and Sons, Ltd.; length 260ft, breadth 41ft 6in, depth 17ft 9in, deadweight 2500 tons; Newbury diesel engine 1200 b.h.p. at 250 r.p.m. Launch, February 8th.

CHLOE, oil tanker; built by the Furness Shipbuilding Company, Ltd., for the Maya Compania Armadora S.A. of Panama; length between perpendiculars 560ft, breadth moulded 80ft, depth moulded 42ft 3in, deadweight 24,575 tons on 32ft 3½in summer draught; twenty-seven cargo oil tanks, two pump rooms, four 500 tons per hour Duplex steam pumps and two stripping pumps, steam deck machinery; two 75kW steam-driven generators, one 35kW diesel-driven generator; N.E.M.-Doxford single-acting, two stroke oil engine, six cylinders 670mm diameter by 2320mm combined stroke, b.h.p. 6800 at 119 r.p.m., two Scotch boilers. Trial, February 18th.

HANSTRUM, oil tanker; built by R. and W. Hawthorn Leslie and Co., Ltd., for Shell Bermuda (Overseas), Ltd.; length overall 557ft, breadth moulded 69ft 3in, depth moulded 39ft, deadweight 18,000 tons; thirty-three cargo oil tanks, one pump room, four vertical centrifugal turbine-driven pumps, pressure ventilation system; two 550kW geared turbine-driven alternators, one 200kW diesel-driven alternator; one set of double reduction geared compound turbines, 8250 s.h.p., steam supplied at 500 lb per square inch and 800 deg. Fah. by two Foster-Wheeler "D" pattern water-tube boilers. Trial, February 18th and 19th.

ESSO CANTERBURY, oil tanker; built by Vickers-Armstrongs, Ltd., at Barrow, for the Esso Petroleum Company, Ltd.; length between perpendiculars 600ft, breadth moulded 82ft 6in, depth moulded 42ft 6in, deadweight 26,650 tons; thirty cargo oil tanks, one pump room, four 3500 gallons per minute turbine-driven cargo pumps, three 585 gallons per minute stripping pumps, steam deck machinery, two 500kW geared turbine-driven alternators, one 60kW diesel-driven alternator; one set of double reduction geared compound turbines, 12,500 s.h.p. service power at 112 r.p.m. of propeller and 13,750 s.h.p. maximum power at 115 r.p.m. of propeller, steam supplied at 850 lb per square inch and 850 deg. Fah. by two Babcock and Wilcox integral furnace boilers. Launch, February 19th.

OUWERKERK, cargo ship; built by the Netherlands Dock and Shipbuilding Company, Amsterdam, for the United Netherlands Navigation Company, The Hague; length between perpendiculars 138·68m, breadth 19·13m, depth 12·42m, draught 8·53m, deadweight 10,260 tons, speed 16 knots; twelve passengers; five cargo holds, derrick complement includes one of 100 tons and one of 30 tons lifting capacity; Stork supercharged, seven-cylinder, single-acting, two-stroke diesel engine, 8500 b.h.p. at 115 r.p.m., three 200kW diesel-driven generators. Launch, February 20th.

Contracts

HUNTING GEOPHYSICS, Ltd., 29, Old Bond Street, London, W.1, has received a contract for a large-scale aeromagnetic survey of iron ore resources in the Philippines. The survey is a project which has been sponsored by the Philippine Council for U.S. aid and the Foreign Operations Administration Mission. The survey will cost about £36,288, to be paid by the F.A.O. and about £8358 to be drawn from Philippine counterpart funds. Flying for the survey will be carried out by a twin-engined Percival "Survey Prince" aircraft, equipped with an airborne magnetometer.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases, the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

Tues., March 23rd.—W. MIDLANDS SECTION: Technical College, Wulfruna Street, Wolverhampton, "Industrial Application of Electronic Instruments," A. G. Wray, 7.15 p.m.

Wed., March 31st.—LONDON SECTION: School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, W.C.1, "Radio Astronomy," R. Hanbury Brown, 6.30 p.m.

INCORPORATED PLANT ENGINEERS

Wed., March 24th.—BLACKBURN BRANCH: Grosvenor Hotel, Blackburn, Annual General Meeting, 7.30 p.m.

Thurs., March 25th.—SHEFFIELD AND DISTRICT BRANCH: Grand Hotel, Sheffield, Annual General Meeting, 7.30 p.m.

Fri., March 26th.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, Annual General Meeting, "Industrial Electrical Maintenance," D. Parkes, 7.30 p.m.

Mon., March 29th.—W. AND E. YORKS BRANCH: The University, Leeds, "High-Frequency Heat-Treatment," K. J. Irvine, 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Wed., March 31st.—LONDON BRANCH: Waldorf Hotel, Aldwych, W.C.2, "Any Questions," 7.30 p.m.

INSTITUTE OF FUEL

Tues., March 23rd.—Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, "Solar Energy for Water and Space Heating," H. Heywood, 5.30 p.m.

INSTITUTE OF MARINE ENGINEERS

To-day, March 19th.—EDUCATION GROUP: 85, Minories, London, E.C.3, Annual General Meeting, Discussion on "The Part the University Has to Play in the Training of the Marine Engineer," opened by A. W. Jones, 5.30 p.m.

Mon., March 22nd.—The Institute, 85, Minories, London, E.C.3, Film, "Lubrication," 6.30 p.m.

Tues., March 23rd.—The Institute, 85, Minories, London, E.C.3, Annual General Meeting, 5.30 p.m.

Wed., March 24th.—SCOTTISH SECTION: North British Hotel, Princes Street, Edinburgh, "A Talk on the Denny-Brown Ship Stabiliser," Sir William Wallace, 7.30 p.m.——JUNIOR LECTURE: S.E. Essex Technical College, Dagenham, "Gas Turbines," G. C. R. Mathieson, 7 p.m.

Thurs., March 25th.—N.E. COAST SECTION: Technical College, Sunderland, "The Heart of a Tanker," H. Nicol, 7 p.m.

INSTITUTE OF METALS

Tues., March 30th.—OXFORD LOCAL SECTION: Cadena Café, Cornmarket Street, Oxford, Annual General Meeting, followed by a Discussion, 7 p.m.

INSTITUTE OF PETROLEUM

To-day, March 19th.—Institution of Electrical Engineers, Savoy Place, London, W.C.2, Symposium on "Metal-Working Oils," C. B. Davies, 2.15 and 5 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., March 23rd.—WORKS MEETING: Great George Street, London, S.W.1, "Design and Construction of Rama VI, Surat and Bandara Bridges in Thailand," O. A. Kerensky and K. E. Hyatt, 5.30 p.m.——MIDLANDS ASSOCIATION: E. Midland Gas Board Demonstration Theatre, Lower Parliament Street, Nottingham, "East Coast Floods," J. Finn, 6.30 p.m.

Fri., March 26th.—N.W. ASSOCIATION: Council Chambers, Chester, "The New Iron-Making and Steel-Making Plant at Shotton, Nr. Chester," J. F. R. Jones, 7.30 p.m.

Tues., March 30th.—AIRPORT MEETING: Great George Street, London, S.W.1, "Construction of a New Runway at Amman, Jordan," A. R. Macrae and A. F. Smith, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., March 22nd.—RADIO SECTION: Savoy Place, London, W.C.2, "Colour Television," C. J. Hirsch, 5.30 p.m.

Tues., March 23rd.—EDUCATION DISCUSSION CIRCLE: Savoy Place, London, W.C.2, "An Experimental and Theoretical Approach to the Teaching of Electromagnetism Using the Rationalised M.K.S. System of Units," F. A. Meier, 6 p.m.

Wed., March 24th.—SUPPLY SECTION: Savoy Place, London, W.C.2, "Cathode-Spot Performance Phases and Control of Mass Transfer in Vapour-Discharge Devices," H. von Bertele, 5.30 p.m.——TEES-SIDE SUB-CENTRE STUDENTS' MEETING: Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "Air Break Switchgear," D. Legg, 6.30 p.m.——N. SCOTLAND SUB-CENTRE: Caledonian Hotel, Inverness, "The Development of Improved Methods of Earthing," J. W. Tolmie and A. Mackenzie, 7.30 p.m.——S.W. SCOTLAND SUB-CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "The Initiation of the Spark and Arc," I. Llewellyn Jones, 7 p.m.

Thurs., March 25th.—ORDINARY MEETING: Savoy Place, London, W.C.2, "The Kemano Hydro-Electric Development and Associated Kitimat Aluminium Reduction Works," F. L. Lawton, 5.30 p.m.

Mon. March 29th.—LONDON STUDENTS' SECTION: Savoy Place, London, W.C.2, "The Mechanism of the Electric Spark and Some Applications," C. Grey Morgan, 6.30 p.m.

Tues., March 30th.—LONDON STUDENTS' SECTION: Drill Hall, 185, London Road, Chelmsford, "Servo Mechanisms," R. A. Middleton, 7 p.m.——N. MIDLAND CENTRE: Royal Station Hotel, York, "Design Features of Certain British Power Stations," S. D. Whetman and A. E. Powell, 7 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., March 23rd.—39, Elmbank Crescent, Glasgow, "Modern Developments in the Design and Manufacture of Welded Pressure Vessels," M. B. Hamilton and J. McIntyre, 6.45 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, March 19th.—ANNUAL GENERAL MEETING: 1, Birdcage Walk, London, S.W.1, Corporate and Non-Corporate Members only, 5.30 p.m.

Tues., March 23rd.—E. MIDLANDS BRANCH: Aveling Barford, Ltd., Grantham, "Control Valves for Direct Hydraulic Presses and the Application of the System to a 1000-Ton Forging Press," F. H. Towler and J. M. Towler, 7.30 p.m.——BIRMINGHAM A.D. CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, "The Motor-Cycle as a Utility Machine," D. W. Munro, 6.45 p.m.

Wed., March 24th.—STEAM GROUP DISCUSSION: 1, Birdcage Walk, London, S.W.1, (1) "Admiralty Policy is to Operate Small Steam Turbine Installations at a Steam Temperature of 850 deg. Fah.: (*a*) Can the Theoretical Thermodynamic Gains from these Conditions be Obtained? (*b*) What is the Optimum Pressure Level in View of the Small Brake Horsepower of the Auxiliary Turbines? (*c*) Is the Use of Plain Carbon Steel at 850 deg. Fah. Satisfactory?" (2) "What Steam Temperature Limit Should be Fixed if the Use of Alloy Steels is to be Avoided, or, Alternatively, is Their Use Justified in Spite of the Increased Manufacturing Difficulties Involved, and are These Manufacturing Difficulties More Apparent than Real?" 6.45 p.m.——SOUTHERN BRANCH: Technical College, Brighton, "Shell Boilers for the Small Industrial User," C. H. G. Hayward, 7 p.m.

Thurs., March 25th.—WESTERN A.D. CENTRE: Grand Hotel, Bristol, "Problems in the Design of an Economical Automobile Gearbox," T. C. F. Stott, 6.45 p.m.

Fri., March 26th.—GENERAL MEETING, HYDRAULICS GROUP: Conference on Hydraulic Mechanisms, 10.30 a.m., 2.30 p.m. and 5.30 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Wed., March 24th.—INFORMAL MEETING: Conference Room, Fourth Floor, Waterloo Bridge House, London, S.E.1, "Some Aspects of the Efficiency Engineer's Job," D. F. Hamilton, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Mon., March 22nd.—MANCHESTER SECTION: Reynolds Hall, College of Technology, Sackville Street, Manchester, "Development of Modern Cutting Tools," N. T. Heaton, 7.15 p.m.

Wed., March 24th.—LIVERPOOL SECTION: Adelphi Hotel, Lime Street, Liverpool, "Induction Hardening," R. H. Barfield, 7.30 p.m.——SHREWSBURY SECTION: Technical College, Shrewsbury, "Industrial X-Ray, Final Interpretation and Acceptance Standards," E. J. Grinwade, 7.30 p.m.——WORCESTER SECTION: Cadena Café, Worcester, "Industrial Incentives," R. N. Marland, 7 p.m.

Thurs., March 25th.—LINCOLN SECTION: Annual General Meeting, followed by a talk by H. Burke, 7.30 p.m.——S. WALES SECTION: S. Wales Institute of Engineers, Park Place, Cardiff, "The Relationship Between Factory Administrative Procedure and Financial Control," W. Crosskey, 6.45 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Thurs., March 25th.—11, Upper Belgrave Street, London, S.W.1, "Gap-Graded Aggregates in Vibrated Concrete," T. E. H. Williams, 5.55 p.m.

INSTITUTION OF WATER ENGINEERS

Wed., March 24th.—S.E. SECTION: Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, Annual General Meeting, 2 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, March 19th.—INFORMAL MEETING: Townsend House, Greycoat Place, London, S.W.1, "A Review of Plastics Piping," B. T. A. Holland, followed by a Film, "The Story of Tenite," 7 p.m.

Mon., March 22nd.—N.W. SECTION: Engineers' Club, Albert Square, Manchester, "Developments and Future Possibilities in Electricity Generation," Sir John Hacking, 7.30 p.m.

Wed., March 24th.—MIDLAND SECTION: Centre Lecture Room, Stewarts and Lloyds, Ltd., Bilston, "Some Aspects in the Choice of Electric Motor Control Gear," J. R. Bell, 7 p.m.

Fri., March 26th.—ORDINARY MEETING: Townsend House, Greycoat Place, London, S.W.1, "The Design and Application of Pipelines for Drainage Works," W. D. Haworth, 7 p.m.

LIVERPOOL ENGINEERING SOCIETY

Wed., March 24th.—24, Dale Street, Liverpool, "Industria Uses of Atomic Energy," H. W. B. Skinner, 6 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

Fri., March 26th.—Engineers' Club, Albert Square, Manchester, Annual General Meeting, "Engineering Aspects of Glass," R. E. Bastick and H. Cooper, 6.45 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Fri., March 26th.—Mining Institute, Newcastle upon Tyne, "Cathodic Protection of Cargo Spaces in Oil Tankers," J. Lamb and E. V. Mathias, 6.15 p.m.

REINFORCED CONCRETE ASSOCIATION

Thurs., March 25th.—College of Technology, Sackville Street, Manchester, "The Design and Construction of Reinforced Concrete Silos and Bunkers," G. P. Bridges, 6.45 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Tues., March 23rd.—12, Great George Street, London, S.W.1, "The Problems of Resettlement in New Communities," R. J. Allerton, 5.30 p.m.

ROYAL SOCIETY OF ARTS

BICENTENARY OF THE ROYAL SOCIETY FOR THE ENCOURAGEMENT OF ARTS, MANUFACTURES AND COMMERCE, 1954

Mon., March 22nd.—Church of St. Martin-in-the-Fields, Trafalgar Square, London, W.C.1, Commemorative Service; Sermon, The Right Rev. The Lord Bishop of Peterborough, 11.30 a.m.——Lecture Hall, John Adam Street, Adelphi, London, W.C.2, Presentation of Congratulatory Addresses by Kindred Bodies and Address by The Right Hon. The Earl of Radnor, Closing Address by The Right Hon. Viscount Samuel, 3 p.m.

Tues., March 23rd.—Lecture Hall, John Adam Street, Adelphi, London, W.C.2, "The Arts, 1754–1954," Nikolaus Pevsner, 3 p.m.

Wed., March 24th.—Lecture Hall, John Adam Street, Adelphi, London, W.C.2, "Manufactures, 1754–1954," Sir Ben Lockspeiser, 3 p.m.

Thurs., March 25th.—Lecture Hall, John Adam Street, Adelphi, London, W.C.2, "Commerce, 1754–1954," Sir Geoffrey Heyworth, 3 p.m.

Fri., March 26th.—Savoy Hotel, London, W.C.2, Banquet, Guests of Honour, T.R.H The Duke and Duchess of Gloucester.

SOCIETY OF ENGINEERS

Thurs., March 25th.—INFORMAL MEETING: 17, Victoria Street, London, S.W.1, "An Australian in London," E. C. Ashcroft 5.30 p.m.

WOOLWICH POLYTECHNIC

Wed., March 24th.—London, S.E.18, "Communication in Industry," A. C. Leyton, 7.30 p.m.